AMPLIFIERS *and* HETERODYNES

Radio Communication Pamphlet No. 9

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The following publication, entitled "Amplifiers and Heterodynes, Radio Communication Pamphlet No. 9," is published for the information and guidance of all concerned.

[062.1, A. G. O.]

BY ORDER OF THE SECRETARY OF WAR:

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General of the Armies,
Chief of Staff.

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P. C. HARRIS,
The Adjutant General.

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AMPLIFIERS AND HETERODYNES.

RADIO COMMUNICATION PAMPHLET NO. 9.

SECTION I.

APPARATUS DESCRIBED IN PAMPHLET.

1. Apparatus described in pamphlet.—A radio set comprises two or more equipments, which together form a set and are given an SCR type number. Each equipment is given a type number, different type numbers being assigned to equipments that vary even in only one particular. The radio equipment, proper, described in this pamphlet varies mainly in the set boxes. It is to be noted that some of these are the same for different SCR numbers; this is because the auxiliary equipment is different, thus necessitating a different SCR number. Receiving T. P. S. sets have been included because they can be used for low frequency amplification, although ground telegraphy itself is no longer used in army communications.

It is the set boxes that are described in detail in this pamphlet. The following data will enable one to find the description desired:

Set box BC–17 is the amplifier of the SCR–72 and SCR–147 sets.

Set box BC–44 is the amplifier of the SCR–72–B and SCR–148 sets.

Set box BC–44–A is the amplifier of the SCR–121 and SCR–121–B sets.

Set box BC–8–A is the amplifier of the SCR–144 set.

Set box BC–101 is the amplifier of the SCR–149 set.

Set box BC–103 is the amplifier of the SCR–145 set.

Set box BC–104 is the heterodyne of the SCR–146 set.

Full parts lists of each set are given in Section XI.

SECTION II.

NOTES ON CARE AND OPERATION OF AMPLIFIERS AND HETERODYNES.

2. Care of apparatus.—All radio apparatus, including amplifiers and heterodynes, must be carefully handled. Rough treatment will surely cause trouble by dislodging or loosening parts of the apparatus, breaking electrical connections, either within the insulation or at the terminals, or, in the case of amplifiers, heterodynes, and other vacuum tube sets, breaking or changing the relative position of the elements of the tube. Therefore, it is necessary to handle radio apparatus with great care. Allowing the apparatus to become damp or wet will, in addition to causing rust and mold to form, nullify the insulating properties of the insulators used and in time destroy them. Radio apparatus should never be stored in a damp place. If unavoidably exposed to rain it should be carefully dried out by placing in a warm room, but never exposed to direct heat.

3. Care of telephones.—The telephones furnished with the amplifiers are type P–11 head sets. These should never be taken apart, as they are ground after assembly to get the exact clearance between the diaphragm and the pole pieces. If it becomes necessary to change the plug or cord, these should be connected in the exact way the old ones were. The connections can be identified by the colored tracer threads running through the insulation of the wires. To test the connection, connect the tip of the plug to the positive lead of a 20-volt dry battery and the ring of the plug to the negative lead. Unscrew the caps from the receivers, remove the diaphragm, and test the strength of the magnet in each ear piece with it. The magnets in both ear pieces should be stronger than the plug is connected to the dry battery than when it is not. If not stronger, proper connections of the cords and plugs have not been made.

4. Operation of heterodynes.—In operating a heterodyne there are two important factors to be considered.. The one factor is the strength of the oscillation set up at the detector by the heterodyne. There is a definite though not critical strength, varying for different received signals, at which the reception is best. The strength of the oscillation set up at the detector by the heterodyne may be varied by changing the strength of the oscillations generated by the heterodyne or by changing the coupling between the heterodyne and the receiving circuits. The strength of the oscillations generated by the heterodyne may be controlled to some degree by control handles, usually rheostats, placed on the heterodyne for this purpose. Changing the coupling between the heterodyne and the receiving circuits may be done by means of a coupling control handle for this purpose, as in the set box type BC–104. If no such control is provided the coupling may be changed by varying the relative position of the heterodyne and the receiving circuits. Increasing the distance increases the coupling. The coupling may be also changed by changing the angle

between the coil of the heterodyne and the coil of the receiving set to which it is coupled. When the two coils are parallel the coupling is greatest; when at right angles the coupling is least.

The other important factor in the operation of the heterodyne is the frequency of the oscillations. The difference between the frequency of the received oscillations and those generated by the heterodyne determines the pitch of the note heard in the receiver and must be equal to an audio frequency. As the frequency of the received oscillations is determined at the transmitting station, these can not be changed at the receiving station. The frequency of the heterodyne, however, is under control and is varied so as to produce the desired audio frequency. The heterodyne frequency is varied by changing either the capacity or inductance in the circuit or by changing both of these. A heterodyne has control handles for this purpose. The setting of these handles is very sensitive. Thus, if the control handles were moved from a setting that gives oscillations whose wave lengths is 600 meters to a setting that gives oscillations whose wave length is 605 meters, the difference in frequency of the two wave lengths would be 4,300. This change in frequency is enough to make the note pass from audibility to inaudibility. So delicate is the apparatus, especially for short wave lengths, that in many heterodynes the approach of the operator's hand to the control handle gives capacity enough to change the note heard in the receivers. The set box type BC–104 is shielded so as to avoid as far as possible any such outside influences. In turning the control handles of a heterodyne a click is sometimes heard in the telephones of the receiving set. This click occurs at the point where the heterodyne oscillations and the received oscillations have the same frequency. It is just to either side of this point that the signals can be heard.

5. Operation of amplifiers.—By means of the rheostats on the set boxes the degree of amplification can be controlled. Use the minimum amount of current that will give readable signals. Interference from other stations may sometimes be eliminated by adjusting the rheostats. Interchanging the vacuum tubes, even in an amplifier, may give better results. If a tube does not light up, clean its contact points and try it again. It may be that the tube is burned out. If so, it must be replaced by a new tube. If the filaments of vacuum tubes are connected in series, the burning out of one tube will prevent the others from lighting. The defective tube can be found by trial and be replaced. A good test for a low-frequency amplifier is to gently tap the first tube. If the amplifier is working properly, a ringing sound will be heard in the telephone receivers.

6. Failure of amplifiers to operate.—Amplifiers may fail to operate even when the filament tubes are lighted. The trouble usually lies

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in the high-volt battery. This should be examined for loose or broken connections, and should be tested as to voltage, which should not fall below 38 volts. A frequent cause of a high-volt battery running down is the storage of these batteries in such a way that their terminals are short-circuited. Short-circuiting a high-volt dry battery for only a few moments will make it worthless. High-volt batteries connected with wrong polarity will prevent the amplifiers from operating and hence should be checked up. If no trouble is found with the batteries, the other connections you have made should be checked up. If no faults are found, the trouble may be in a loose or broken connection within the set box.

7. **"Howling" of amplifier.**—Sometimes an amplifier "howls" or "sings." This drowns out the signals. There are numerous causes for this howling. A loose, broken, or dirty connection of the high-potential battery will cause it, as will also leakage or local action in that battery. The remedy lies in correcting the fault in the connections or battery. Another source of howling lies in a defective vacuum tube which, to the eye, is apparently in good condition. Such a tube must be replaced. It can be found by trial. Allowing the leads from the filament battery, the high-volt battery or to the telephones to touch each other is liable to cause howling, especially if these leads are free to move or swing against each other. The most frequent cause of howling, however, is too great a filament current. This can be controlled by the rheostat, usually placed on the amplifier. If there is none on the amplifier, an outside one can be connected in series with the filament battery. If the fault is not located among the above, grounding the negative terminal of the filament battery will often prevent howling. Insulating the amplifier from the ground has been found helpful in some cases. Sometimes reversing the input connections will eliminate the howling. It must be remembered that very often the foreign noises heard in the receivers of an amplifier are not caused by the amplifier but are due to other causes such as atmospherics, nearby electrical circuits or machinery, etc.

SECTION III.

AMPLIFIER SET BOX, TYPE BC–17 (Used in SCR–72 and SCR–147 sets).

8. **Purpose of amplifier.**—This set box is an audio frequency amplifier using VT–1 tubes, giving two stages of amplification. There is no detector and therefore the receiving set with which it is used must be provided with one, or a separate one must be used. The

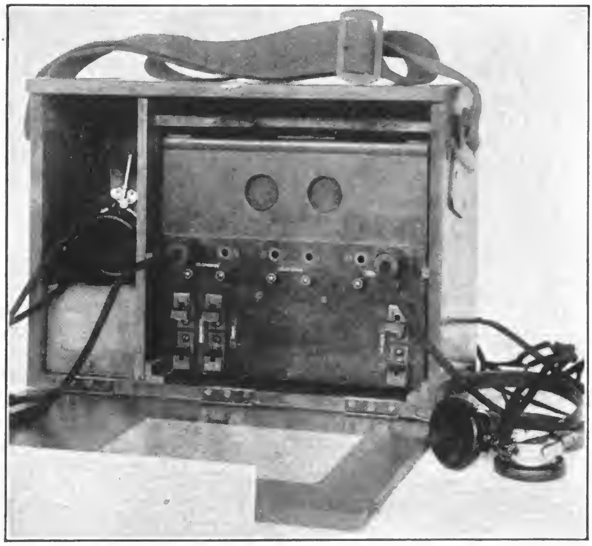

FIG. 1.—AMPLIFIER SET BOX, TYPE BC-17, IN ITS CARRYING CASE.

amplifier may be used for radio signals after detection, or for ground telegraphy signals. The latter use, however, is now obsolete. It was designed mainly for that use, and together with batteries and accessory equipment, was called set T. P. S. receiving, type SCR–72.

9. The amplifier set box.—The amplifier apparatus proper, together with the high-potential batteries, is contained in one box. This box measures 10½ by 6 by 10¼ inches high and weighs 13 pounds. It is carried in a carrying case having compartments for accessories and spares. A view of the amplifier in its carrying case is shown in figure 1. The front of the amplifier contains windows through which the two vacuum tubes can be seen. There is also a panel which bears telephone jacks and binding posts or Fahnestock clips. There are six telephone jacks arranged in pairs, which are in parallel. The pair to the left is used when it is not desired to use any amplification. The next pair is used for one stage of amplification, and the third pair for both stages. Beneath each pair of telephone jacks are two terminals to which a telephone head set may be connected if it is not provided with a plug to fit the jacks. On the lower left of the panel are two pairs of terminals or Fahnestock clips, suitably marked, to which the input to the amplifier is connected. The left pair is for ground telegraphy; the other pair for radio. On the lower right side of the panel are the terminals or Fahnestock clips to which to connect the 4-volt storage battery used for lighting the filament of the tubes.

10. The interior of the set box.—Access to the interior of the amplifier box is obtained by raising the cover of the box. On either side are compartments with Fahnestock clip terminals for carrying the high-potential batteries. Between these compartments is a space for the vacuum tubes, whose sockets are mounted on a shelf cushioned from mechanical vibration by being supported on a sponge rubber. Beneath this shelf are the intertube transformers, which are of the heavy iron-clad type, and other pieces of small apparatus.

11. Installing the BC–17.—(*a*) Connect the 4-volt storage battery leads to the terminals "+4 volt—" being sure to observe the proper polarity. If using the cord and battery provided with the set, do not plug into the battery until it is desired to receive signals. If using separate wires do not attach to battery until it is desired to receive signals.

(*b*) Open cover of the box and place a BA–2 battery in each compartment, face up and negative wire (black) to the rear. Connect the terminals to the clips provided, observing the proper polarity as marked on the edge of the compartment. (The rear terminal clips on each compartment are negative.)

(*c*) Place two VT–1 tubes in their sockets.

(*d*) Connect the output of the radio receiving set to the terminals marked "Radio." The polarity of the connection makes no difference in the working of the amplifier. (The output of a radio receiving set having a detector is where one would connect the telephone if no amplifier were being used.)

(*e*) Plug in the phones—preferably in one of the right-hand pairs of jacks. Finish the connection to the storage battery and the set is ready for operation.

12. **Operating the BC–17.**—There are no controls on the amplifier. sometimes better amplification can be obtained by interchanging the two tubes. If the amplifier "sings" or "howls" it can usually be stopped by grounding the negative terminal of the filament battery. When the amplifier is not in use, the filament battery should be disconnected from the set. Disconnect at the battery rather than at the set box.

Section IV.

AMPLIFIER SET BOXES TYPE BC–44 (used in SCR–72–B and SCR–148 sets) and TYPE BC–44–A (used in SCR–121 and SCR–121–B sets).

13. **Purpose of amplifiers.**—The amplifiers, type BC–44 and BC–44–A, are two stage audio frequency amplifiers, using VT–1 tubes. The BC–44 was designed to receive ground telegraphy signals as well as radio signals and has an extra terminal for this purpose. This is the only essential difference between the two set boxes. There is no detector in the amplifiers and hence an outside detector must be used in receiving radio signals before they can be amplified by these sets.

14. **The amplifier set boxes.**—All parts of the amplifier, except the 4-volt storage batteries, are carried in one box, which is divided into two compartments. The compartment to the left is to be used for storing the telephones and other accessories when they are not in use. The other compartment is closed by a bakelite panel. A cover, which can be clamped on a rubber gasket, protects the front of the set box. The set box, with its cover on, measures 16 by 8½ by 10 inches high, and with its spare parts and accessories weighs approximately 24 pounds. It is provided with a web carrying strap. Figure 2 shows a view of the BC–44 set box with its cover removed. The front panel of the set box bears terminals, marked "+B Batt— " for an external 40 volt battery, terminals marked "+4 volt—" for the filament storage

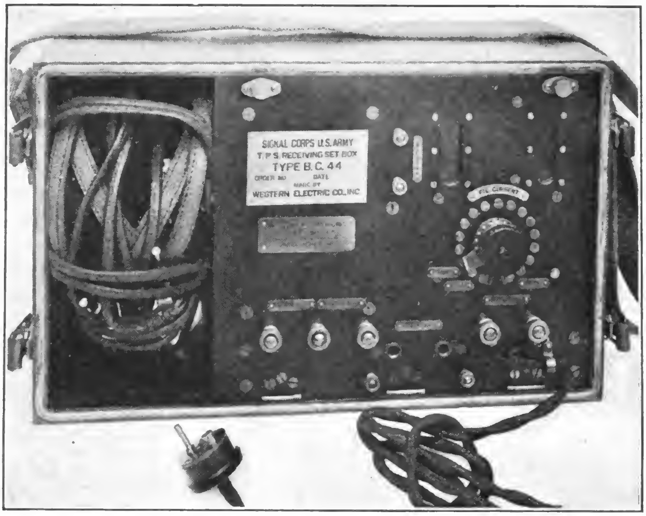

FIG. 2.—AMPLIFIER SET BOX, TYPE BC-44, FRONT VIEW.

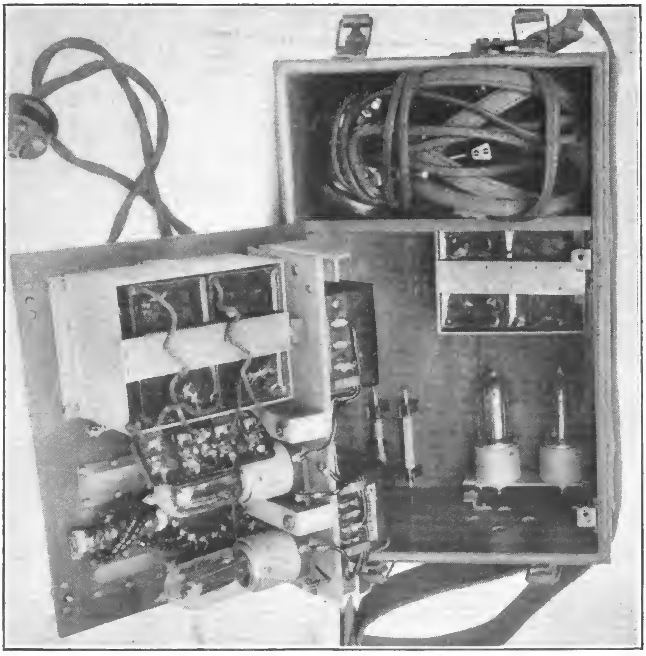

FIG. 3.—AMPLIFIER SET BOX, TYPE BC-44, INTERIOR VIEW.

battery, and terminals underneath two jacks marked "Phones" to which telephones may be connected if they are not provided with plugs to fit the jacks. There are also input terminals mounted on the panel. In the BC–44 these are three terminals, marked "Amplifier" and "Ground telegraphy." In the BC–44–A there is only one pair of terminals, marked "Amplifier." The panel also bears a clip under which the 4-volt battery leads may be fastened. A filament rheostat handle, marked "Fil current," is the only control on the amplifier.

15. The interior of the set boxes.—Access to the interior of the compartment carrying the radio equipment comprising the amplifier is gained by unscrewing a knurled knob in each upper corner and pulling forward the panel, which is hinged at its lower edge. The radio equipment in use, including a case for holding the high-volt batteries, is all mounted on the rear of the panel. A view of the interior of the BC–44 set box, with the vacuum tubes and high-volt batteries installed, is shown in figure 3. The transformers, which are of the iron-clad type, are mounted underneath the shelf carrying the vacuum tubes. The vacuum tubes are cushioned from jars by being mounted in sponge rubber. The small cylindrical objects with beaded insulated leads are resistances of the filament rheostat. Behind the apparatus mounted on the panel is a space containing suitable holders for the carrying of spare dry batteries, vacuum tubes, and resistances.

16. Installing the BC–44 or the BC–44–A.—(*a*) Turn "Fil current" rheostat to the "Off" position.

(*b*) Connect a 4-volt storage battery to the terminals marked "+ 4 volts –," being sure to observe proper polarity.

(*c*) Unscrew the knurled screw in each upper corner and pull the panel forward. Place in the holder mounted on the rear of the panel two BA–2 batteries with their faces up. Fasten the terminals of each battery to the Fahnestock clips, being sure to observe proper polarity. It is to be noted that the inner two clips are both positive and the outer two both negative. The rear pair of clips is to be used for the rear battery, the front pair for the front battery. Make all connections tight and clean.

(*d*) If the BA–2 batteries are not available, an external 40-volt battery should be connected to the terminals in the front of the panel marked "+ B Batt –." Observe the proper polarity as marked on the panel.

(*e*) Place a VT–1 tube in each of the two sockets, close and fasten the panel.

(*f*) Connect the two terminals of the output of the detector to the two binding posts marked "Amplifier." (The output terminals of the detector are where the telephones would be connected if no amplifier were used.)

(*g*) Plug in the telephones in the jack marked "Phones" or connect each lead of the telephone to one of the terminals immediately below the jack and the set is ready for operation.

17. Operating the BC–44 or the BC–44–A.—Turn the "Fil current" rheostat clockwise until the tubes burn a cherry red. There are no other controls on the amplifier. The receiving apparatus must be tuned and the detector adjusted in the usual manner. The amount of amplification can be controlled somewhat by the filament rheostat. Turning the handle of this rheostat to the right increases the amplification. It must be remembered that this increases the brilliancy of the tubes and shortens their life. If the amplifier howls the filament current should be reduced. If this does not eliminate the trouble, try grounding the negative terminal of the filament battery.

SECTION V.

AMPLIFIER SET BOX, TYPE BC–8–A (used in SCR–144 set).

18. Purpose of amplifier.—This set box is designed to amplify and detect damped wave signals. By the use of a separate heterodyne undamped waves may also be received and amplified. There are three stages of radio frequency amplification, followed by a detector tube and two stages of audio frequency amplification. Six VT–1 tubes are used. The amplification is greatest for waves whose length is 1,000 meters, but satisfactory amplification is obtained over wave length ranges of from 750 to 1,500 meters.

19. The amplifier set box.—The amplifying apparatus, except the batteries and certain accessories, is mounted in a box which measures 15½ by 6 by 8¼ inches high and weighs 10 pounds. The front of the box, shown in figure 4, is a bakelite panel on which are mounted the terminals and control handles. Along the lower edge of the panel are two pairs of terminals, the left-hand pair, properly marked, being for the 4-volt filament storage battery; the other pair, also properly marked, being for the 40-volt plate battery. The two terminals along the right edge of the panel are the input terminals, the upper one being marked "Grid" and the lower one "Fil." There is a telephone jack, marked "6 tubes," to plug in the telephone when it is desired to use the full amplification furnished by the set. Immediately below this is a telephone jack marked "5 tubes" for use when it is not desired to employ the second audio frequency amplify-

FIG. 4.

AMPLIFIER SET BOX, TYPE BC-8-A, FRONT VIEW.

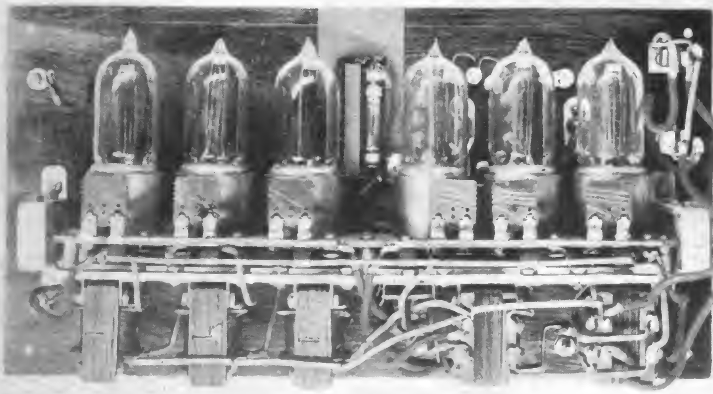

FIG. 5.

AMPLIFIER SET BOX, TYPE BC-8-A, INTERIOR VIEW.

ing tube. The panel bears two control handles; the one to the left marked "Fil control" turns on and off the filament battery. The other control varies the current passing through the filaments of the high frequency amplifying tubes. It is marked "Fil. Rheo H. F."

20. The interior of the set box.—Access to the interior of the set box is gained by raising the cover, which is hinged at the rear. A shelf, supported in sponge rubber pads, carries sockets for the six vacuum tubes. Viewing the box from the front, the three tubes to the right are used for radio frequency amplification; the fourth tube is used as a detector, and the remaining tubes for audio frequency amplification. A view of the interior of the set box is shown in figure 5. The radio frequency and the audio frequency transformers are mounted below the shelf. The filament resistance for each tube appears in front of the tube sockets. The narrow tube between the third and fourth vacuum tube is the grid leak resistance. It is to be noted that the whole apparatus is carried on the front panel.

21. Installing the BC–8–A.—(*a*) Place "Fil. control" switch to the "Off" position.

(*b*) Connect a 4-volt storage battery to the binding posts marked "+Fil Bat—, 4 V." Observe the correct polarity as marked.

(*c*) Connect two 20-volt batteries (BA–2 or BA–8) in series to the binding posts marked "+Plate Bat—, 40 V." It is very important that all connections be clean and tight and that the proper polarity is observed.

(*d*) Place six VT–1 tubes in their sockets, which are made accessible by opening the lid of the box. It may be found later that interchanging the tubes will give better results. Certain tubes are better amplifiers or detectors than others. This can be determined by trial.

(*e*) Connect the two terminals of the output of the receiving set to the two terminals on the right of the set box marked "Grid" and "Fil." If the radio receiving set has one side grounded, this side should be connected to the "Fil" binding post. If it is not known whether or not the receiving set has one side grounded, the proper connection can be found by trial. Use that connection which gives the best results. It is to be noted that this set box can be used only when the radio receiving set has no detector.

(*f*) Insert the telephone plug into whichever jack it is desired to use and the set is ready for operation.

22. Operating the BC–8–A.—Turn the "Fil Rheo H.F." control handle to the "Min" position. Turn the "Fil control" handle to the "On" position. Now turn the "Fil Rheo H. F." handle clockwise until the filaments of the three tubes to the right become a cherry red in color. The radio receiving set should be tuned in the

regular manner. Control of the amount of amplification is secured by the operation of the "Fil Rheo H. F." handle. In general this should be as close to the "Min" position as is possible, while maintaining signals of suitable strength. If there is a tendency for the amplifier to howl, the filament current must be reduced. Howling is more frequent when using the six tubes than when using only the five tubes.

Section VI.

AMPLIFIER SET BOX, TYPE BC-101 (used in SCR-149 set).

23. Purpose of amplifier.—The amplifier, type BC-101, is a vacuum tube amplifier, using either three VT-1 or three VT-5 tubes. There are two stages of audio frequency amplification in addition to a detector tube. A switch is provided to use the detector tube together with the amplifier tubes or to use the amplifier tubes alone. Thus the amplifier can be used with a receiving set that contains a detector or with one that does not contain a detector. As only audio frequencies are amplified, this apparatus, like all other audio frequency amplifiers, is independent of the wave length of the radio signals.

24. The amplifier set box.—The whole apparatus, except the storage batteries and certain accessories, is mounted in a box constructed of an aluminum frame which supports bakelite panels. The box is $8\frac{1}{2}$ inches by $6\frac{3}{4}$ inches by 10 inches high and weighs $10\frac{1}{2}$ pounds. The terminals and controls are all mounted so as to be nearly flush with the projecting sides of the box. The binding posts are all mounted on these extended sides; the two to the left marked "Grid" and "Fil" being the input terminals. At the bottom to the left are the terminals for the filament battery marked "Fil Bat 4 V or 2 V,— and +"; to the right of these are terminals for the 40-volt plate battery marked "Plate Bat, — and +." On the left are two terminals connected together by a copper strip which is removable. These terminals are for the insertion of a reactance coil when one is desired and are marked "Tickler." The front panel carries a double throw switch, one position of which, marked "Detector," throws the detector tube and the two amplifier tubes in circuit; the other position, marked "Amplifier," throws only the two amplifier tubes in circuit. To the right of this switch is a rheostat marked "Fil con-

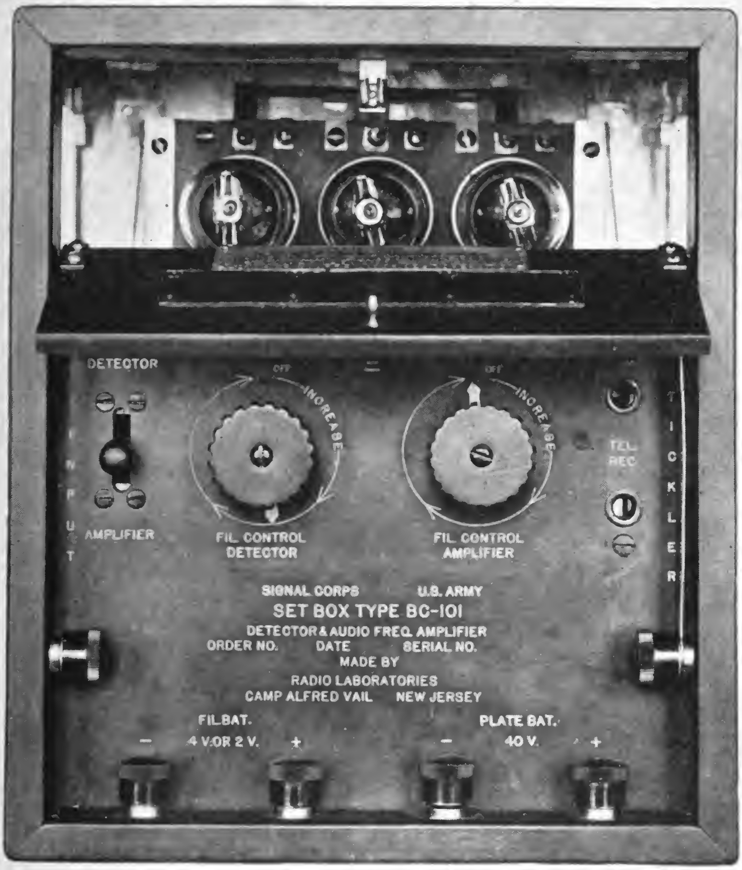

FIG. 6.

AMPLIFIER SET BOX, TYPE BC-101, FRONT VIEW.

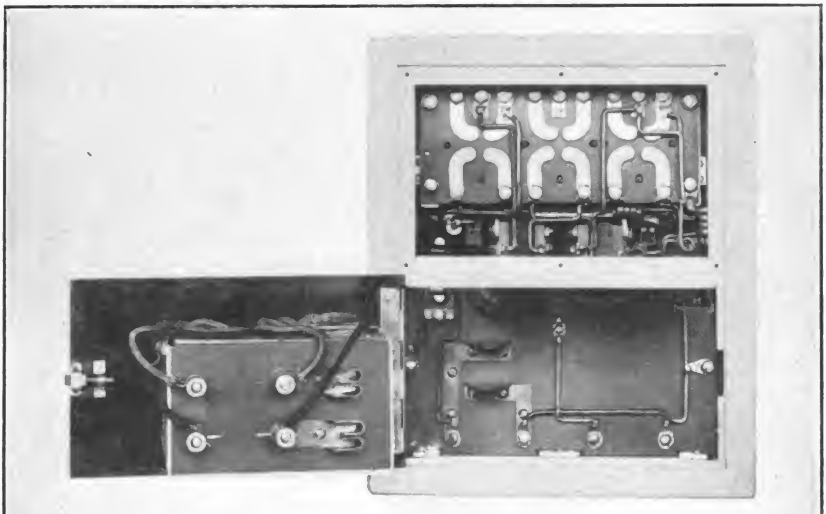

FIG. 7.

AMPLIFIER SET BOX, TYPE BC-101, INTERIOR VIEW.

trol detector" for controlling the filament current of the detector tube. To the right of this is another rheostat marked "Fil control amplifier" for controlling the filament current of the two amplifier tubes. There are also two telephone jacks, in parallel, so that two pairs of telephone receivers can be plugged in. The upper part of the front panel is a door, having three small windows. The door permits access to the interior of the set for putting in the vacuum tubes. Figure 6 shows a view of the set box with this door open.

25. The interior of the set box.—The aluminum frame of the box carries brackets which support a shelf mounted between sponge rubber pads to absorb mechanical vibration. This shelf carries the vacuum-tube sockets and attached to the underside of it are the transformers and various small pieces of apparatus. The lower half of the back of the set box is a door which has mounted on it a frame having terminals for the two BA–2 batteries used in the set. Connections of these batteries are completed inside the box by spring clips which engage when the door is closed. A view of the set box from the rear, with the upper panel removed and with the door open is shown in figure 7. It is to be noted that the BA–2 batteries are in place in their holders. The back of the vacuum-tube sockets are seen in the upper part of the view. The two audio frequency transformers can also be distinguished. Mounted on the inside of the right panel as viewed from the rear are supports which carry adapters (type FT–65) when these are not in use. Those adapters are to fit in the vacuum-tube sockets when VT–5 tubes are used. They can not be seen in the illustration.

26. Installing the BC–101—using VT–5 tubes.—(*a*) Turn "Fil control detector" counterclockwise to the "Off" position. Do same to the "Fil control amplifier."

(*b*) Connect a 2-volt storage battery or a closed circuit (ignition type) dry cell to binding post marked "Fil Bat, 4 V or 2 V." Be sure to observe correct polarity as marked on the set box.

(*c*) Open rear door and place in the holder mounted thereon two type BA–2 dry batteries. Place these batteries face up with their positive terminals (red wires) next to the door. Fasten the batteries in the holder by means of the copper strip spring provided, spreading the wires apart so that there are no wires between the spring and the face of the batteries. Obeying the following rule: "*Do not connect the terminals from the same BA–2 battery to the two terminals on the holder which are connected by a copper strip*," connect the four terminals of the two batteries to the four terminals provided on the holder, observing the proper polarity. Be sure to have all connections clean and tight. Press all the wires down so that they lie close to the batteries. After removing the adapters from their holders inside the box, close the door.

(*d*) If BA–2 batteries are not available a 40-volt battery must be connected to the terminals on the front of the box marked "Plate Bat 40 V." Be sure to observe correct polarity as marked in the set box.

(*e*) Open the door on the front panel and place an adapter in each vacuum-tube socket. Place VT–5 tubes in the adapters and close the door. It may be found later that interchanging the tubes will give better results. Certain tubes are better amplifiers or detectors than others. This can be determined by trial.

(*f*) Connect the two terminals of the output of the radio receiving set to the two terminals marked "Input, grid and fil" on the left of the amplifier. If the radio receiving set has one side grounded, this grounded side should be connected to the "Fil" terminal. If it is uncertain whether or not the radio receiving set is grounded, the proper connection can be found by trial. The connection which gives the best resulting signal should be used.

(*g*) Throw the double switch down to the "Amplifier" position if the receiving set has a detector that is being used; otherwise throw the double-throw switch up to the "Detector" position. Plug in the phones and the amplifier is now ready for operation.

27. Installing the BC–101—using VT–1 tubes.—(*a*) Follow directions given in subparagraph (*a*) of paragraph 26.

(*b*) Connect a 4-volt storage battery to the binding posts marked "Fil Bat, 4 V or 2 V." Be sure to observe correct polarity as marked in the set box.

(*c*) Follow directions of paragraph 26 (*c*) to 26 (*g*), inclusive, except that the adapters are not to be used.

28. Installing the BC–101—using a reactance coil.—(*a*) Follow directions either of paragraph 26 or 27, according to the type of vacuum tube to be used. The tickler terminals should be connected to the "tickler" or "feed back" or "reactance coil" in the receiving set, if there be any, when it is desired to receive undamped wave signals. It may be found necessary to reverse the connections to the amplifier tickler terminals to get the proper coupling. This can be determined by trial. When using a tickler the short-circuit strip between the two terminals on the amplifier should be disconnected at the upper terminals.

(*b*) If the receiving set has no tickler coil and there is no other method of receiving undamped waves, a method using this amplifier can be devised. The necessary conditions are that an inductance of the proper value connected to the tickler terminals be inductively coupled to the secondary receiving inductance of the receiving set. The amount of inductance to be used will vary with the type of receiving set, and also to some degree with the wave length of the incoming signals. The inductance to be used and its position may be

found by trial. Start by winding No. 24 silk-covered magnet wire in a single layer on a cylinder about 4 inches in diameter, leaving fairly long leads. The turns should be close together and there should be enough turns to make the coil about 1 inch wide. Attach the leads to the tickler terminals and place the coil near to and parallel with the secondary receiving inductance. If no results are obtained, turn over the coil you have made. If success is still lacking, try the coils in various positions with respect to the secondary receiving inductance, inverting the coil in each position. If still unsuccessful, change the number of turns on the coil and try again.

29. Operating the BC–101.—(*a*). Turn the "Fil control amplifier" switch clockwise until the two tubes to the right show a cherry red. If the detector tube is being used, do the same with the "Fil control detector." However, if the amplifying tubes only are used the detector tube is out of circuit and will not light up.

(*b*) Tune the receiving set in the usual method.

(*c*) Adjust the detector and amplifier tubes by means of their filament controls to give the most readable signals. It must be remembered, however, that burning the tubes too brightly greatly shortens their lives.

(*d*) If the amplifier howls or sings, try decreasing the brightness of the tubes, especially the amplifier tubes.

(*e*) When the amplifier is not in use, turn both filament-control switches counterclockwise to the "Off" position.

Caution.—If the BC–101 is used with other tube sets it should be furnished with a separate filament battery, otherwise the plate battery of the other set may be short-circuited.

SECTION VII.

AMPLIFIER SET BOX TYPE BC–103 (used in SCR–145 set).

30. Purpose of amplifier.—The amplifier, type BC–103, is designed to amplify, or detect and amplify, radio signals whose wave lengths are from 1,000 to 3,000 meters. It will amplify signals of other wave lengths, but the best amplification is produced within the above range. There are provisions made for three stages of radio frequency amplification, followed by detection, and two stages of audio frequency amplification. There are provisions made also for the use of the two audio frequency stages only. The amplification given by the latter is independent of the radio wave length of the signal. Six VT–1 tubes are used in the amplifier.

31. The amplifier set box.—The whole apparatus, except the batteries and certain accessories, is contained in a set box whose dimensions are 15½ by 6 by 8¼ inches high, and whose weight is approximately 10 pounds. The front of the box is shown in figure 8. There are terminals to which to connect the plate and filament batteries, and also two sets of terminals to which to connect the output of a radio receiving set. The terminals to the right marked "Grid" and "Fil" are to be used when the radio receiving set has no detector, or one which is not in use. The terminals at the lower center are to be used when the radio receiving set has a detector that is being used. In addition to these terminals the panel carries a filament control switch for turning off and on the current in the filament; a filament rheostat that controls the amount of current in the high frequency amplifying tubes; a two-way switch that must be thrown to the proper position when the amplifier is used for either of its two purposes; and an amplification switch which controls the amount of amplification produced by the high frequency amplifying tubes. There are two telephone jacks on the left of the panel. The lower one marked "5 tubes," uses only one stage of audio amplification; the upper one marked "6 tubes," uses both stages. All terminals and control switches are appropriately marked.

32. The interior of the set box.—The top of the set box is hinged so as to permit access to the six tube sockets. These sockets are for the VT–1 tubes used in the set and are mounted on a shelf. The three tubes to the right are the radio frequency amplifiers, the fourth tube from the right is the detector; the other tubes are audio frequency amplifiers. Mounted on the lower side of the tube shelf are transformers and other pieces of equipment. The tube shelf is cushioned against jars and vibration by sponge rubber, and is supported by brackets attached to the bakelite panel. Access to the apparatus for repairs can be had by removing the panel, which is held in place by machine screws. Fig. 9 shows how the apparatus is mounted on the back of the panel. In the figure, three radio frequency transformers are seen at the lower left and two audio frequency transformers at the lower right. The narrow tube between these two sets of transformers is the grid leak resistance.

33. Installing the BC–103.—(*a*) Place "Fil control" switch on "Off" position.

(*b*) Connect a 4-volt storage battery to the binding posts marked "4 V." Be sure to observe the correct polarity as marked on the set box panel.

(*c*) Connect two 20-volt batteries (BA–2 or BA–8) in series to the binding posts marked "40 V." Be sure to observe the correct polarity. It is especially important that all connections of these batteries be *clean* and *tight*.

FIG. 8.

AMPLIFIER SET BOX, TYPE BC-103, FRONT VIEW.

FIG. 9.

AMPLIFIER SET BOX, TYPE BC-103, INTERIOR VIEW.

(*d*) Place six VT-1 tubes in the sockets which are made accessible by opening the lid of the box. It may be found later that interchanging the tubes will give better results. Certain tubes are better amplifiers or detectors than others. This can be determined by trial.

(*e*) *For audio frequency amplification* (*used when the radio receiving set has a detector which is in use*).—Connect the two terminals of the output of the radio receiving set to the two terminals on the lower center of the box marked "Audio amplification." The polarity of the connection makes no difference in the working of the amplifier. (The output terminals of the radio receiving set are at the jack or binding posts to which the telephones would be connected if no amplifier were being used.)

Throw the double throw switch in the upper center of the panel *down* to the position marked "Audio."

(*f*) *For radio frequency amplification* (*used when the radio receiving set has no detector or one that is not in use*).—Connect the two terminals of the output of the radio receiver to the two terminals on the right of the amplifier marked "Input," one being labeled "Fil" and the other "Grid." If the radio receiving set has one side grounded, this grounded side should be connected to the "Fil" terminal. If it is uncertain whether or not the radio receiving set is grounded, the proper connection can be found by trial. The connection which gives the best resulting signals should be used.

Throw the double throw switch in the upper center of the panel *up* to the position marked "Radio."

(*g*) Insert the telephone plug into whichever of the jacks marked "5 tubes" or "6 tubes" it is desired to use. The amplifier is now ready to use.

34. Operating the BC–103.—(*a*) *For audio frequency amplification.*—There is only one control switch, the "Fil control" switch. When it is desired to receive signals this should be turned to the "On" position. The two vacuum tubes should light up. Nothing more need be done to the amplifier.

(*b*) *For high frequency amplification.*—There are three controls for the operation. The "Fil control" switch is thrown to the "On" position which causes all the tubes to light up. The other controls marked "Fil rheo H. F." and "Amplification" are for controlling the amount of amplification of the tubes. In general the "Fil rheo H. F." should be adjusted so that the high frequency amplifying tubes show the same brilliancy as the low frequency tubes. The degree of amplification can still further be controlled by turning the "Amplification" switch—turning in a clockwise direction gives greater amplification. If this switch does not give as great a control of the amplification as desired, the "Fil rheo H. F." may be used. Increasing the brilliancy of the tubes by this switch increases

the degree of amplification; decreasing the brilliancy decreases the amplification. In some cases the amplifier will "sing" or "howl," due to oscillations being set up in it. Such "singing" or "howling" prevents the reading of the signals. If they occur they can usually be stopped by moving the "Fil rheo H. F." switch one or two contacts toward "Min" and decreasing the degree of amplification by means of the "Amplification switch." Sometimes in addition to the above it is necessary to turn the "Fil control" to the "Off" position for an instant before the "howling" or "singing" will disappear. Howling is more frequent when using the six tubes than when using only the five tubes.

SECTION VIII.

HETERODYNE SET BOX TYPE BC–104 (used in SCR–146 set).

35. Purpose of the heterodyne.—The heterodyne, type BC–104, is a VT–1 oscillator designed to set up weak oscillations over a frequency range corresponding to wave lengths of between 800 and 3,400 meters. These weak oscillations are used in the reception of undamped waves of the same range of wave length by the heterodyne method. The heterodyne may be used as a wavemeter. (See Radio Communication Pamphlet No. 28.) It must be remembered that, when used for this purpose, the results may not be so strictly accurate as if obtained by an instrument designed primarily as a wavemeter.

36. The heterodyne set box.—The whole apparatus, except the batteries and certain accessories, is mounted in a box which measures 8 by 9 by 11½ inches high and weighs 12 pounds. The front of this box is shown in figure 10. On the lower edge of the front panel are binding posts for connecting the batteries, the pair to the left being for the 4-volt battery; the pair to the right for the 40-volt battery. In the upper left corner is a binding post for the antenna lead in wire, and in the upper right a binding post for connecting to the receiving set used. There is a "Fil control" switch for turning on and off the filament current; a "Coupling" control handle for varying the coupling between the circuits of the oscillator proper and the circuit which is a part of the antenna lead in wire. A double throw switch to the left controls the amount of inductance in the oscillating circuits, thus enabling the variable air condenser to have

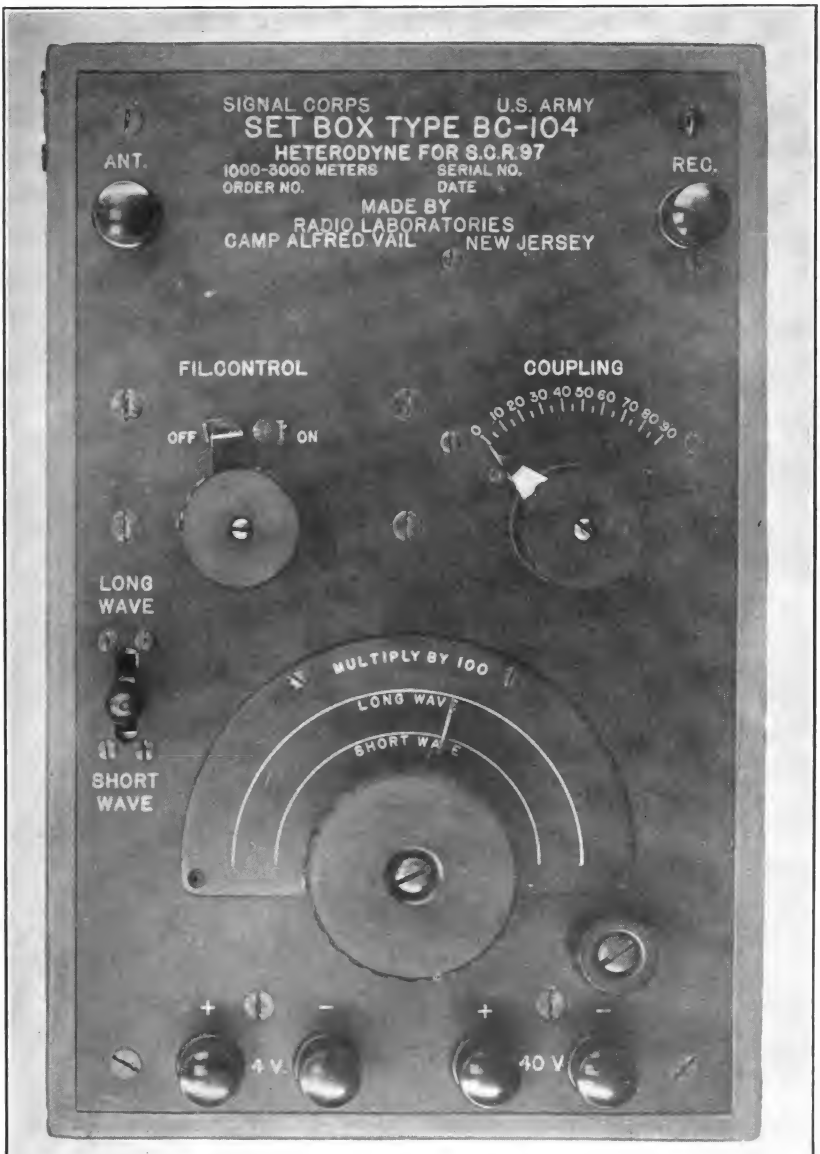

FIG. 10.

HETERODYNE SET BOX, TYPE BC-104, FRONT VIEW.

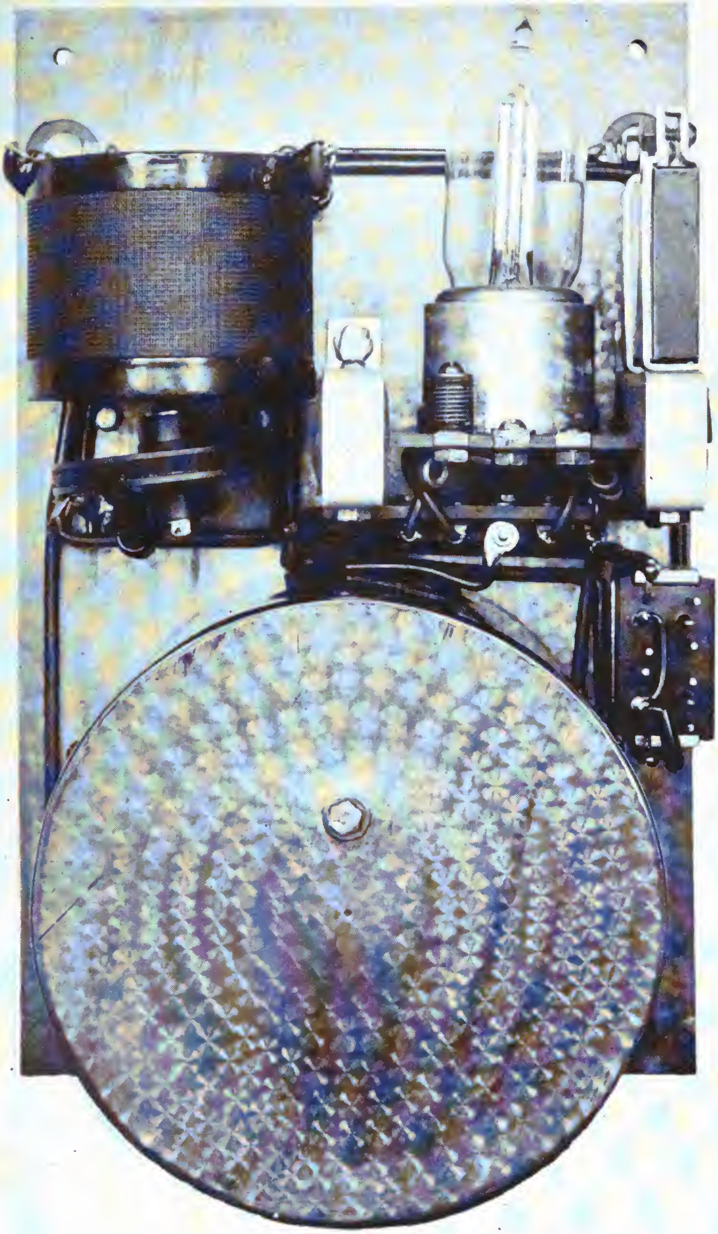

FIG. 11.

HETERODYNE SET BOX, TYPE BC-104, INTERIOR VIEW.

two ranges of wave length. The variable air condenser gives wave lengths of from 800 to 2,000 when the double throw switch is thrown down to the " Short-wave " position, and gives wave lengths of from 1,400 to 3,400 when the double throw switch is thrown up in the "Long-wave" position. The reading on the scale of the variable condenser should be multiplied by 100 to give the wave length. The air condenser is controlled for coarse adjustments by a large knob. For fine adjustments it is controlled by a small knob placed at the lower right of the large knob. When using the coarse-adjustment knob the smaller knob should have its gears disengaged. This is done by pulling the smaller knob slightly outward.

37. The interior of the set box.—The whole apparatus is mounted on the front panel of the box, which is lined throughout with copper to prevent any electrical field set up by the oscillator from being picked up by the antenna or other receiving apparatus. The variable air condenser is thoroughly shielded also so as to reduce to a minimum outside influences affecting the frequency of the oscillations. A view of the interior of the set box is shown in figure 11. On the large coil at the upper left is wound both the plate and the grid inductances, the latter having two taps. The small coil below contains the antenna inductance and rotates around a horizontal axis so as to provide different degrees of coupling with the coil above. The vacuum tube is mounted on a shelf supported by sponge rubber held in brackets on either side. The shelf also carries the filament resistance. The condenser shown at the right of the tube is the high-frequency by-pass condenser shunted across the 40-volt battery terminals. Below this condenser is a switch which is so designed that it has no appreciable electrical capacity. The large variable air condenser appears at the bottom of the illustration.

38. Installing the BC–104.—(*a*) Throw the " Fil control " switch to the " Off" position.

(*b*) Connect a 4-volt storage battery to the terminals marked " 4 V," being sure to observe the proper polarity.

(*c*) Connect a 40-volt battery (two type BA–2 or two type BA–8 in series) to the terminals marked " 40 volts." Be sure to have all connections tight and clean as well as observing the proper polarity.

(*d*) Raise the lid of the box and put a VT–1 tube in its socket.

(*e*) Connect the antenna lead-in wire to the binding post marked " Ant."

(*f*) Connect the binding post of the heterodyne marked " Rec " to the binding post of the receiving set marked " Ant " or other similar designation.

(*g*) Turn the " Fil control " to the " On " position and the set is ready for operation.

39. Operating the BC–104; receiving set calibrated—wave length known.—(*a*) Tune the receiving set to the wave length to be received.

(*b*) Place the double throw switch of the heterodyne either in the long wave or short wave position, depending upon the wave length to be received.

(*c*) Turn the "Coupling" handle until the pointer shows a coupling of 20 degrees.

(*d*) Pull outward the small fine adjustment knob of the variable condenser.

(*e*) Set the pointer of the variable condenser on the wave length to be received, using the large knob.

(*f*) Press in the fine adjustment knob so that its gears are meshed and turn *slowly* back and forth until the note is heard in the telephones and is of the proper pitch.

(*g*) Readjust the "Coupling" until the note heard in the telephones is of the proper intensity. The fact that the receiving set also needs final adjustment must not be overlooked.

40. Operating the BC-104; receiving set not calibrated—wave length known.—(*a*) Place the double throw switch of the heterodyne either in the long wave or short wave position, depending upon the wave length to be received.

(*b*) Turn the coupling handle until the pointer shows a coupling of 20 degrees.

(*c*) Pull outward the small fine adjustment knob of the variable condenser.

(*d*) Set the pointer of the variable condenser on the wave length to be received, using the large knob.

(*e*) Press in the small fine adjustment knob until the gears mesh.

(*f*) Put the secondary of the receiver on *aperiodic* if it has this arrangement.

(*g*) Adjust the coupling control in the receiver to give the maximum coupling.

(*h*) Vary the tuning of the primary of the receiver (and secondary also if there is no periodic arrangement) and at the same time turn the fine adjustment knob of the heterodyne slowly back and forth. It is not necessary to move the knob more than a third of a turn either side of its first position.

(*i*) After the signal has been picked up make final adjustments.

41. Operating the BC-104; receiving set calibrated—wave length unknown.—(*a*) Place the double-throw switch of the heterodyne in short-wave position.

(*b*) Turn the coupling handle until pointer shows a coupling of 20°.

(*c*) Pull outward the small fine adjustment.

(*d*) Set the pointer of the variable condenser on the shortest marked wave length.

(*e*) Press in the fine-adjustment knob until the gears mesh.

(*f*) Tune the receiving set to the wave length to which the heterodyne has been set, using a close coupling.

(*g*) Turn the fine-adjustment knob of the heterodyne slightly back and forth, not moving it more than a third of a turn from its original position.

(*h*) If the signal is not picked up, turn the variable air condenser of the heterodyne to the next lowest wave length and repeat as above.

42. Operating the BC–104; receiving set not calibrated—wave length unknown.—This is a difficult task and requires much patience. It can be done by placing a variable condenser of the heterodyne on a definite wave length and tuning the primary and secondary of the receiving set. The receiving set should have the closest possible coupling between its primary and secondary. If there is an arrangement for making the secondary aperiodic, this should be done. The broadest kind of tuning should be used until the signal is picked up. The fine-adjustment knob of the heterodyne should be turned slightly back and forth with each setting of the receiver tuning elements. If the signals are not picked up, the heterodyne should be placed on another wave length and the process repeated. In order to receive the signal it is necessary that the frequency of the primary of the receiver, the secondary of the receiver, and the heterodyne be approximately the same. These conditions can be brought about by trial as described above.

Section IX.

PRINCIPLES OF AMPLIFIERS.

43. Definition of amplification constant.—A vacuum tube can be used as an amplifier because, under correct conditions, a voltage applied to the grid has a greater effect upon the plate current than the same voltage applied to the plate. This may be expressed more accurately as follows: A change in the grid potential produces μ' times as great a change in the plate current as an equal change in the plate voltage. The quantity, μ', is called the amplification constant of the tube, and is the maximum voltage amplification that can be obtained from the tube. Mathematically μ' can be expressed as $\frac{de_p}{de_g} = -\mu'$ where e_p and e_g are respectively the plate and grid potentials.

44. Value of amplification constant.—The amplification constant depends upon the structure and geometry of the tube. The mesh of the grid, the diameter of the grid wires, the distance between grid and plate, and between grid and filament are the more important factors which determine the value of this constant. The value of μ' may vary under extreme conditions of voltages applied to the tube but for ordinary operating ranges it may be considered as an unchanging value. μ' equals 6.5, very nearly, in the VT-1 tubes used in Signal Corps amplifiers.

45. Operating conditions for amplification.—In order to secure amplification certain conditions must be obtained. The filament must be hot enough to emit enough electrons so that the plate current is not limited by the number of electrons available. The plate voltage must be high enough to establish a strong electric field within the tube. The potential of the grid should at all times be sufficiently negative so that it will not absorb appreciable current and thus distort the grid voltage-plate current characteristic of the tube. The average potential of the grid with respect to the filament is designated by the term "biasing potential." In addition, for distortionless amplification, the voltage applied to the plate should be of such a value as to keep the dynamic characteristic of the tube as near a straight line as is possible with the external circuits used. The high impedance generally used in the plate circuit produces this condition.

46. Limit and control of amplification.—It has been shown (Thermionic Vacuum Tube, Van der Bij 1) that the voltage amplification of a tube as available across an external resistance is in the plate circuit expressed by:

$$\frac{e_p}{e_g} = -\frac{\mu'}{1+\frac{R_p}{R_e}}$$

where R_p and R_e are respectively the internal plate resistance of the tube and the external resistance, and where e_p and e_g are the effective alternating voltages of the plate and grid. An inspection of this equation shows that the ratio $\frac{e_p}{e_g}$ will increase with a *decrease* of the plate resistance and will also increase with an *increase* of the external resistance. If the external resistance becomes infinite, $\frac{R_p}{R_e}$ becomes zero, and the right-hand number of the equation becomes $-\mu'$. This means that the voltage amplification produced by a tube is limited to the amplification constant of the tube. The plate resistance of the tube depends mainly upon the geometry of the tube, but also depends upon the filament emission and average grid potential. The filament emission is changed with a change in temperature of the filament, and hence it is seen that an amplification produced by

a tube can be controlled to some degree by a rheostat placed in its filament circuit.

47. Low frequency amplifiers.—It is standard practice to have the output of one low frequency amplifier tube pass through the primary of a transformer, the secondary of which is connected to the grid and filament of the next tube. In this manner advantage is taken of the step up in voltage produced by the transformer as well as the amplification produced by the first tube. It can be shown that with an ideal transformer in which the coupling is tight and the load circuit is resistive only, the ratio of grid voltage between successive tubes is expressed by the following equation:

$$\frac{e_{g2}}{e_{g1}}=\frac{\mu' n\frac{R_{g2}}{R_{p1}}}{n^2+\frac{R_{g2}}{R_{p1}}}$$

where e_{g2}=effective alternating voltage on grid of 2nd tube.
e_{g1}=effective alternating voltage on grid of first tube.
μ'=amplifying constant of 1st tube.
n=ratio of secondary to primary voltage in transformer.
R_{g2}=alternating current grid-filament resistance of 2nd tube.
R_{p1}=alternating current plate-filament resistance of 1st tube.

An inspection of this equation shows that if $\frac{R_{g2}}{R_{p1}}$ becomes infinite, the ratio of grid voltage becomes equal to $\mu' n$ which is the maximum possible value. The plate resistance of the tube is inherent in the design of the tube and can not be made equal to zero, but the grid resistance of the second tube can be made very large by placing the right biasing potential on it, although it can not be made infinite because of the residual gas in the tube and surface leakage in connections. If the finite ratio $\frac{R_{g2}}{R_{p1}}$ and the amplification constant, μ', are kept constant, it may be shown by plotting that $\frac{e_{g2}}{e_{g1}}$ is a maximum when $n^2=\frac{R_{g2}}{R_{p1}}$. Substituting this ideal value of n in the basic equation, it is found that the maximum amplification, i. e. $\frac{e_{g2}}{e_{g1}}$ becomes equal to $\frac{1}{2}\mu' u$.

The above discussion is based upon an ideal transformer and takes no account of the no-load reactance, the leakage induction, and the core losses met with in a real transformer.

The effect of these is to reduce the value of the voltage ratio attainable. Considering only the no-load reactance of the transformer (the other quantities can be made small) it can be shown that the best ratio of transformation, n, is 4 or 5 to 1, that the ratio of grid voltages increases with an increase of the grid-filament resistance of

the second tube, that the ratio of grid voltages is not the same for all frequencies, and that the latter depends mainly upon the no-load reactance of the transformer primary. The effect of frequency upon the amplifying power of the tube is shown in figure 12, taken from "Principles of Radio Communication" (Morecroft) and upon which this presentation is based. The curves of the figure show the theoretical relation between the ratio of the potentials of two successive grids and the frequency. The plate-filament alternating current resistance is equal to 10,000 ohms; μ' equals 6, and n equals 4. In curves A, B, and C the grid-filament alternating current resistance

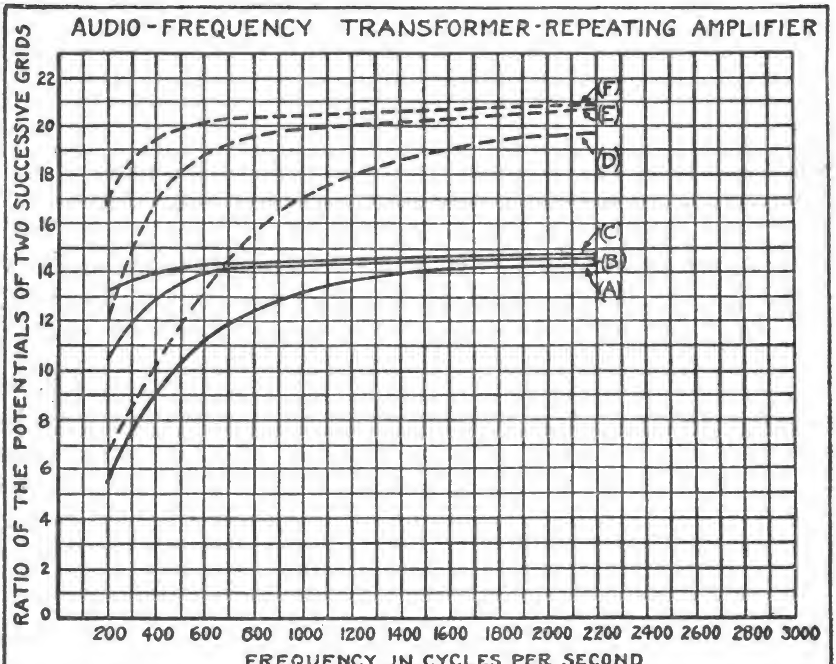

FIG. 12.

is equal to 250,000 ohms; the no-load inductance of the repeating transformer primary is equal to 2 henries in curve A, to 5 henries in curve B, and to 10 henries in curve C. In curves D, E, and F the grid-filament alternating current resistance is equal to 1,000,000 ohms; the no-load inductance of the repeating transformer primary is equal to 2 henries in curve D, to 5 henries in curve E, and to 10 henries in curve F.

If the amplifier is used in radio telephony it is important that the amplification be the same for all frequencies, otherwise speech distortion would result. The conditions upon which this can be obtained may be seen in the figure.

48. Comparison of low frequency and high frequency amplifier.—Because of the small effect at low frequencies it is unnecessary to take into account many phenomena that become important at high frequencies, and hence the designing of a low frequency amplifier is a much simpler task than that of a high frequency amplifier. With high frequency the small capacity of the tube and its leads become of prime importance. It is standard practice in the Signal Corps to use iron core intervalve transformers between high frequency amplifying tubes as well as between low frequency amplifying tubes. The iron core of the transformer adds to the difficulty of calculating the electrical constants. A high frequency transformer works best over a certain range of wave lengths if it possesses high efficiency.

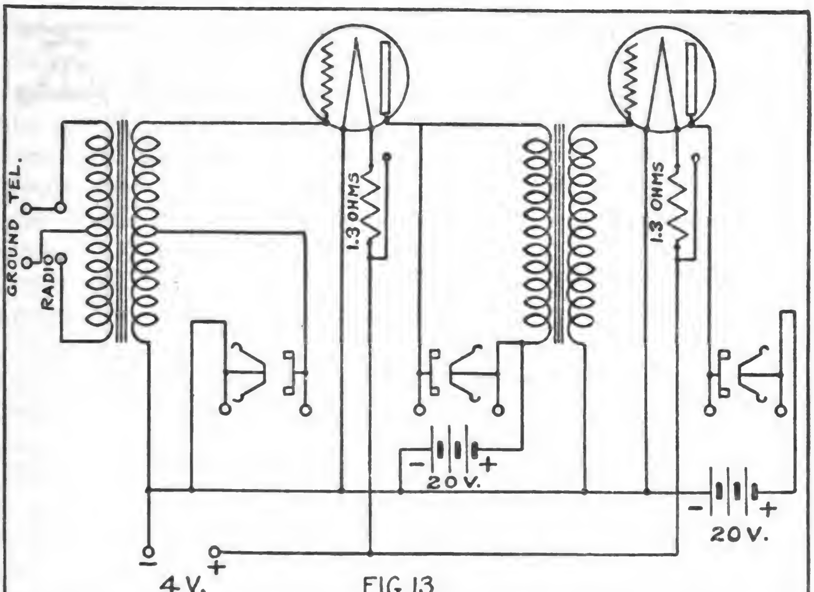

FIG. 13.

Section X.

PRINCIPLES EMBODIED IN THE SET BOXES AND THEIR CIRCUIT DIAGRAMS.

49. Amplifier Set Box Type BC–17.—This amplifier is a low frequency amplifier using iron core transformers. The circuit diagram is shown in figure 13. It is to be noted that connections are provided for tele-

phones so as to use one, two, or no stages of amplification. The plate voltage is 20 volts, there being one battery for each tube. The filaments are connected in parallel and no filament rheostat is provided. The grid is connected to the negative side of the filament. The drop in potential through the secondary of the transformers is sufficient to keep the grid at the negative potential that insures good operation. There are four input terminals arranged in two pairs. One pair uses the whole of the primary of the transformer, while the other pair uses only a part of it. Certain vacuum tubes require a greater filament voltage than others. In these tubes the positive terminal of the filament is permanently connected to the metal base of the

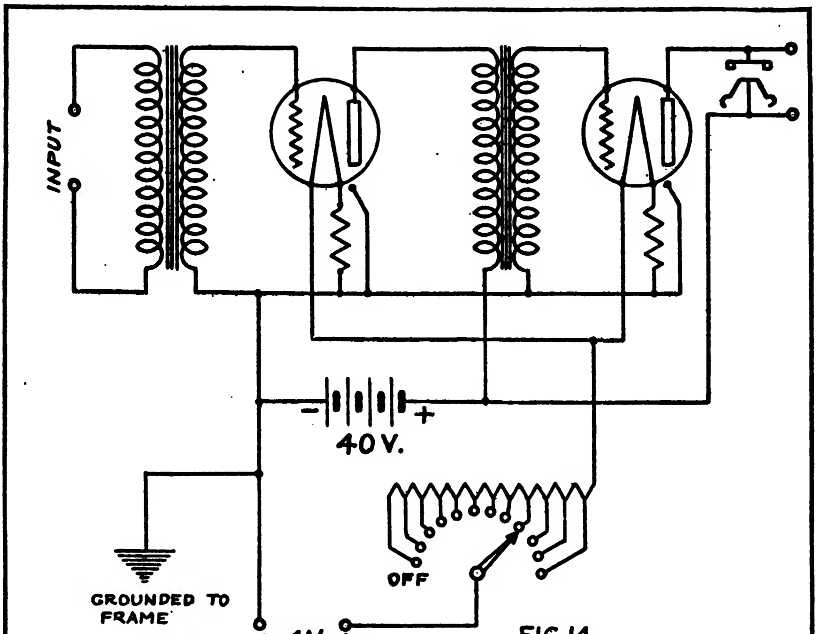

FIG. 14.

tube, and connection is installed in the amplifier from the metal socket to the positive side of the filament resistance whereby the resistance is thus automatically short circuited when a tube of this type is inserted. These tubes are, however, no longer standard Signal Corps equipment.

50. Amplifier set boxes type BC-44 and BC-44-A.—These amplifiers are identical except that the BC-44-A, whose circuit, as shown in figure 14, is provided with only one pair of input terminals, whereas the BC-44 is provided with two pairs similar to the BC-17 set box. These amplifiers are similar to the BC-17 amplifier, except that a rheostat is provided in the filament circuit; no provision is made to

use any except the total amplification that can be produced by the set, and the plate voltage is 40 volts instead of 20 volts.

51. Amplifier set box type BC-8-A.—This is an amplifier having three stages of radio frequency amplification followed by detection and two stages of audio frequency amplification. The circuits are shown in figure 15.

The radio frequency signal impressed on the grid of the first tube appears in amplified form as a radio frequency component of the direct current in the plate circuit. The plate direct current is supplied by the 40-volt battery through the primary of a radio frequency iron core transformer. The impedance of the primary causes a radio frequency voltage to be set up across it by the radio frequency current. This voltage is stepped up by the secondary winding because of its larger number of turns, and this increased voltage is then impressed on the grid. The second and third radio frequency amplifier tubes and the third radio frequency amplifier tube and the detector tube are coupled together in the same manner by radio frequency iron core transformers.

Radio frequency transformers operate best over a certain range of wave length. The transformers used in this amplifier operate well between 750 and 1,500 meters. Due to the fact that stray coupling always exists between the plate and grid circuits of an amplifier, the amplifier tends to generate oscillations. Such oscillations occur at that frequency at which the total losses of the amplifier are a minimum. This condition is also that at which maximum amplification is obtained. As the quality of the signal received is very poor when the amplifier is oscillating, it is desirable to operate the amplifier at the point just short of that at which oscillations occur, as it is at this point that the best readable signals are obtained. One of the factors that determines whether or not a tube will generate oscillations is the plate resistance. By adjusting the plate resistance the tube may, if other conditions permit, be brought to the point just short of oscillating. In order to secure this critical adjustment a rheostat is placed in series with the filaments of the radio frequency amplifier tubes. By varying the filament current the electron emission is varied. This changes the plate resistance and hence gives a control over one of the factors producing oscillations. The filament circuits of the three radio frequency amplifier tubes each contain a 0.5-ohm resistance, the common filament rheostat furnishing the balance of the resistance necessary in the filament circuits.

The transformers in the plate circuit of the third radio frequency amplifier tube has its secondary connected in series with the grid circuit of the detector tube. The detector tube circuit is of the type using a gridleak resistance and a condenser. The grid circuit is connected to the filament circuit so that the voltage drop across the

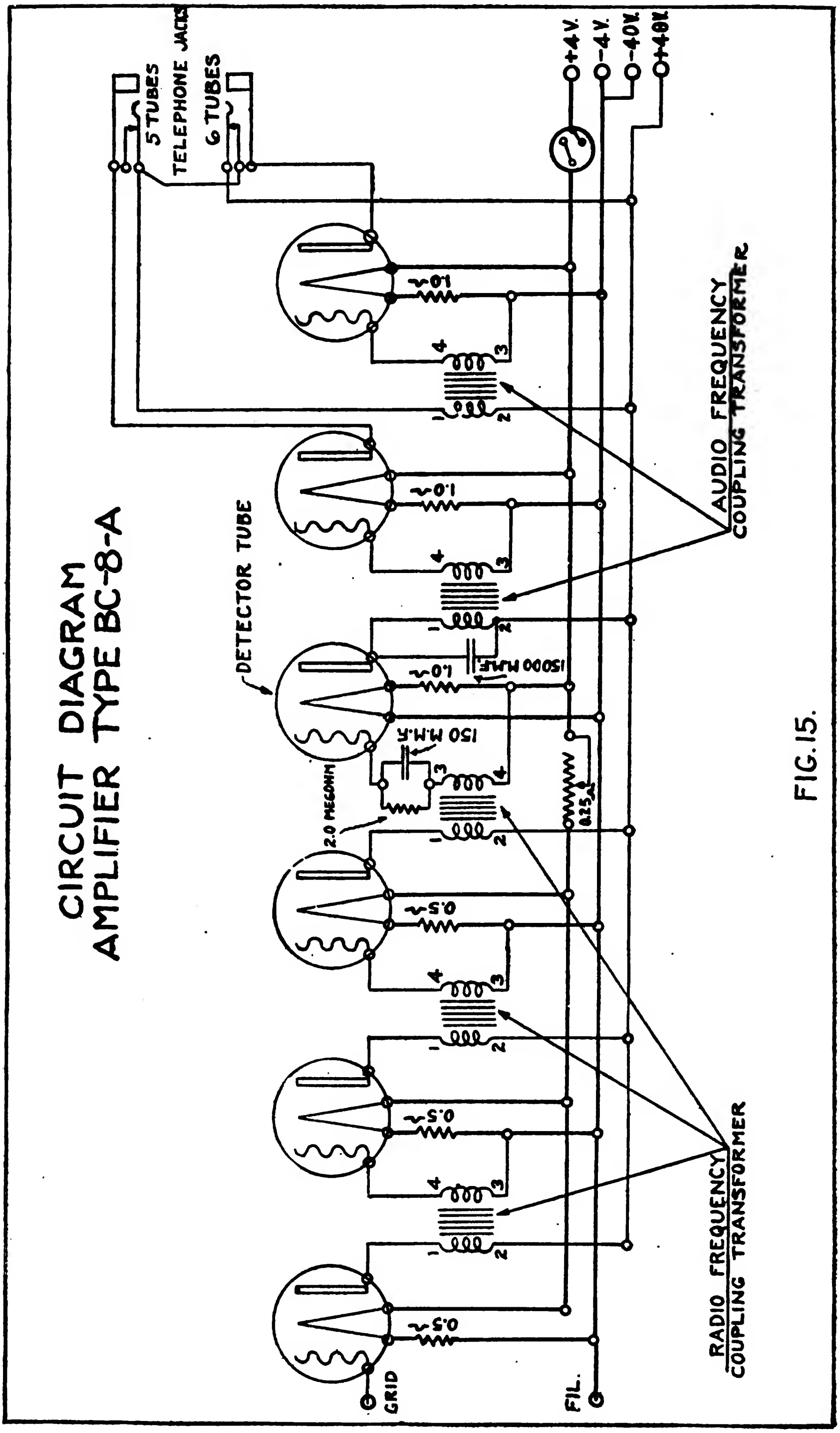
CIRCUIT DIAGRAM
AMPLIFIER TYPE BC-8-A
TELEPHONE JACKS
5 TUBES
6 TUBES
+4 V.
-4 V.
-40 V.
+40 V.
DETECTOR TUBE
15000 M.M.F.
150 M.M.F.
2.0 MEGOHM
AUDIO FREQUENCY
COUPLING TRANSFORMER
RADIO FREQUENCY
COUPLING TRANSFORMER
GRID
FIL.

FIG. 15.

1.0-ohm resistance in the filament circuit places a positive biasing potential upon the grid. This potential is supplied through a 2-megohm gridleak resistance. The positive biasing potential causes a steady grid current to flow, the value of the current being such that the operation is located at the greatest bend of the *grid* current-*grid* voltage curve (using proper plate voltage). The incoming radio frequency signal then undergoes an effective rectification in the grid circuit. Because of the bend in the curve, the positive half of the cycle causes an increase in current that is greater than the decrease in current caused by the negative half of the cycle. The radio frequency voltage therefore causes a pulsating direct current to flow through the grid condenser. The action of the condenser is to store up these radio frequency pulsations. The condenser is charged so that the side connected to the grid becomes negative. The only way the negative charge can be dissipated is by a current passing through the 2-megohm resistance. As the voltage across the condenser is very small, an appreciable length of time is required to discharge the condenser energy. This time lag causes the radio frequency charges to build up so that the condenser charges and discharges at the group or spark frequency. The plate voltage is sufficient to make available the full amplification of the tube. The negative voltages appearing on the grid at the group of spark frequency are reproduced as an alternating current component of the direct current in the plate circuit. The plate current is supplied from the 40-volt battery, the primary of an audio frequency transformer being included in series with the battery. A radio frequency by-pass condenser of 0.0015 m. f. capacity is provided across the transformer primary.

The audio frequency current in the detector tube plate circuit has its potential stepped up by means of the audio frequency transformer, so that the largest possible potential is impressed on the grid of the first audio frequency amplifier tube. The amplifier audio frequency current obtained in the plate circuit of that tube is again amplified in a similar manner by the second audio frequency amplifier tube. Telephone jacks are provided in the plate circuits of both tubes so that either one or two stages of audio frequency amplification can be used as desired. When only one stage is used the telephone head set is connected in series with the plate circuit of the first audio frequency amplifier tube, and the audio frequency transformer primary in that circuit is shorted.

Provision is made for the use of only one stage of audio frequency amplification, because while increased amplification strengthens the signal, it also strengthens all interfering noises due to static, mechanical vibrations, audio frequency induction from near-by electrical apparatus, etc. Often, therefore, a weaker signal can be read more easily because of the reduction of intensity of interfering noises.

83564—22——3

The current in the filament circuits of the two audio frequency tubes is limited to the proper value by 1 ohm resistances placed in each circuit. The potential drop across the resistance in the filament circuit of the tubes is used to furnish a negative biasing potential, which is applied to the grids of both audio frequency amplifier tubes.

52. Amplifier set box type BC–101.—This detector-amplifier is a vacuum tube detector and two-stage audio frequency amplifier. The circuit diagram is shown in figure 16. A switch is provided to enable the detector tube to be disconnected, if desired, in order to use the detector tube which may be included in the radio-receiving set. When the switch is thrown to "Detector" the input binding post marked "Grid" is connected to the grid of the detector tube. When the switch is thrown to "Amplifier" the input binding post marked "Grid" is connected to one terminal of the primary of the first audio frequency transformer. The other side of the primary of this transformer is then connected to the input binding post marked "Fil." The input binding posts are connected to the grid and filament of the detector tube when the switch is thrown to "Detector," and are connected to the primary of the first audio frequency transformer when the switch is thrown to "Amplifier." When the switch is thrown to "Amplifier" the filament circuit of the detector tube is opened.

When the switch is thrown to "Detector" the radio frequency voltages developed across the secondary circuit of the radio receiving set are impressed directly between the grid and filament of the detector tube. The 1.05-ohm resistance in the detector tube filament circuit is used to place a proper negative biasing potential on the grid. The plate current for the detector tube is furnished from the 40-volt battery through the primary of an audio frequency transformer and a 0.5 megohm resistance. The resistance is by-passed for both audio and radio frequency currents by a 0.15 m. f. condenser. The primary of the audio frequency transformer is by-passed for radio frequencies by a 0.005 m. f. condenser. The effective value of plate voltage and the value of negative biasing potential on the grid are such that the value of plate current obtained is located on the greatest bend of the *grid* voltage *plate* current curve. This causes one-half of the radio frequency cycle to be amplified more than the other half of the cycle. An audio frequency current is thereby set up having the frequency of the spark signal or the heterodyne beat note signal.

Two binding posts are provided in series with the plate circuit of the detector tube. The binding posts are normally connected together, but the connecting strap may be removed and a tickler coil forming part of the radio receiving set connected between the bind-

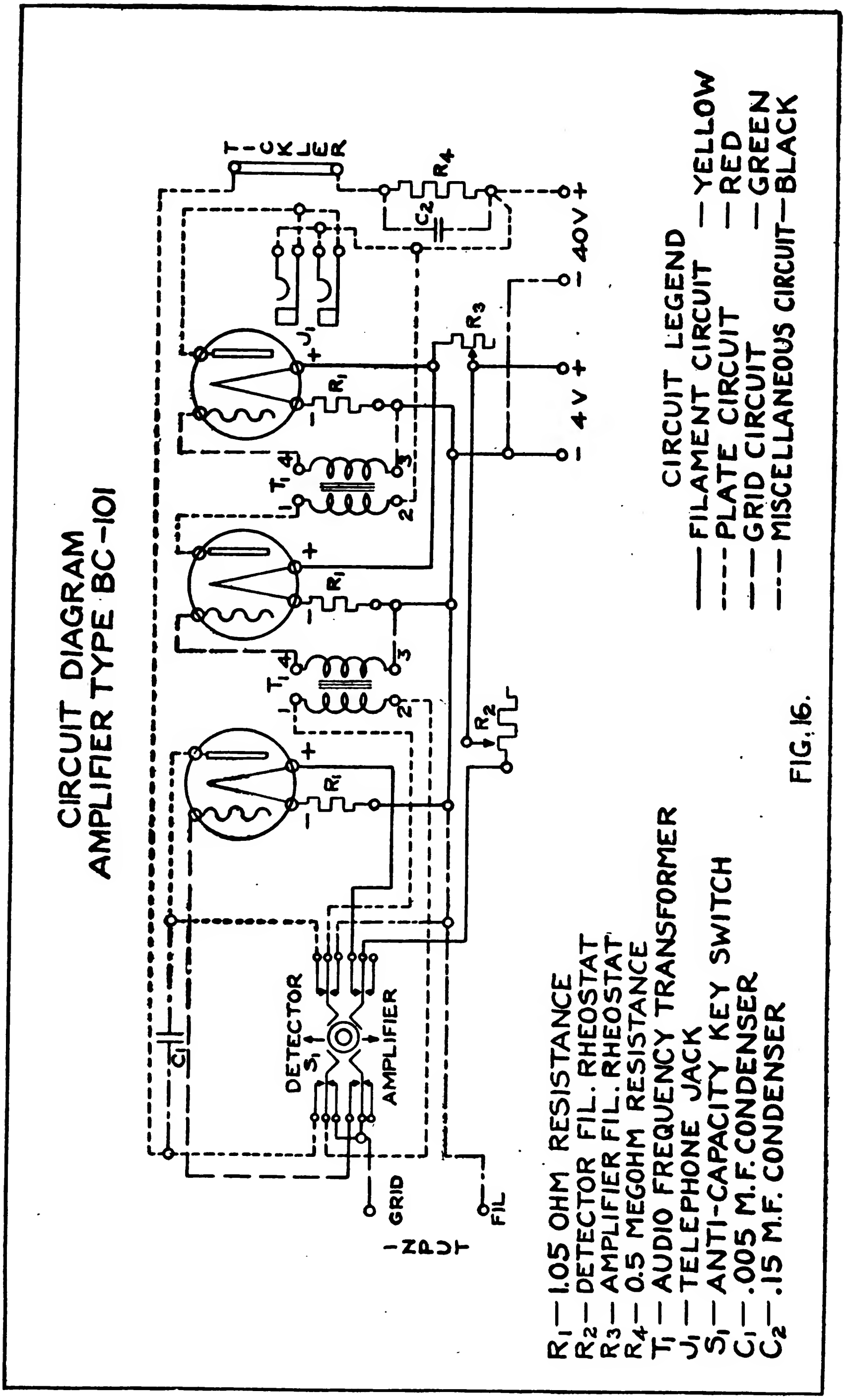
CIRCUIT DIAGRAM
AMPLIFIER TYPE BC-101
TICKLER
R4
C2
40V
J1
R3
4V
R1
T1
DETECTOR
S1
AMPLIFIER
C1
GRID
FIL
INPUT
CIRCUIT LEGEND
—— FILAMENT CIRCUIT —YELLOW
--- PLATE CIRCUIT —RED
—— GRID CIRCUIT —GREEN
— MISCELLANEOUS CIRCUIT—BLACK
R1 — 1.05 OHM RESISTANCE
R2 — DETECTOR FIL. RHEOSTAT
R3 — AMPLIFIER FIL. RHEOSTAT
R4 — 0.5 MEGOHM RESISTANCE
T1 — AUDIO FREQUENCY TRANSFORMER
J1 — TELEPHONE JACK
S1 — ANTI-CAPACITY KEY SWITCH
C1 — .005 M.F. CONDENSER
C2 — .15 M.F. CONDENSER

FIG. 16.

ing posts. By means of the tickler coil the detector tube circuit can be made regenerative for the purpose of strengthening spark or other damped wave signals, or can be made to oscillate for the purpose of heterodyning undamped wave signals.

When the switch is thrown to "Amplifier" the audio frequency voltages developed in the plate circuit of the detector tube forming part of the radio receiving set are impressed across the primary of the audio frequency transformer connected to the first audio frequency amplifier tube.

The operation of the audio frequency amplifier tube is the same whether the detector circuit forming part of BC–101 or a separate detector is used, and is analogous to the low-frequency stages of the BC–8–A amplifier. The current in the filament circuits of the three tubes is limited to the proper value for the VT–1 tube operated from a 4-volt battery by means of a 1.05-ohm resistance placed in each circuit. The potential drop across this fixed resistance in the filament circuit of each tube is used to furnish a negative grid biasing potential. It will be noted that the normal operating current for VT–1 tube filaments is determined by the 1.05-ohm fixed resistance in the circuit of each tube, with the filament control rheostats turned clockwise until the resistance is all cut out.

Type VT–5 tubes require 0.25 ampere at 1.1 volts. When VT–5 tubes are used in the BC–101, a 2-volt storage battery or one closed circuit (ignition) type dry cell (1.4 volts) is connected to the filament battery binding posts. The detector tube filament circuit contains a rheostat providing a maximum resistance of 10 ohms. The two amplifier tube filament circuits are supplied through a common rheostat providing a maximum resistance of 5 ohms. The rheostats provide ample resistance range for operating the VT–5 tubes from the battery sources mentioned above. The detector tube and amplifier tubes are supplied through separate rheostats because the detector tube may require a slightly different value of current for best operation than the value required for amplifier tubes. A control of amplification, using either VT–1 or VT–5 tubes, is obtained by varying the filament control rheostat in the circuit of the amplifier tubes.

53. Amplifier set box, type BC–103.—This is an amplifier having 3 stages of radio frequency amplification, followed by a detector and 2 stages of audio frequency amplification. By means of a switch and separate terminals provision is made for the use of only the audio frequency amplification when desired. When thrown to the audio amplification position, the switch opens the filament circuit of the four tubes that are not in use. The circuit diagram is shown in Fig. 17. The amplifier resembles the BC–8–A amplifier. It differs mainly in that a control in addition to the filament control is

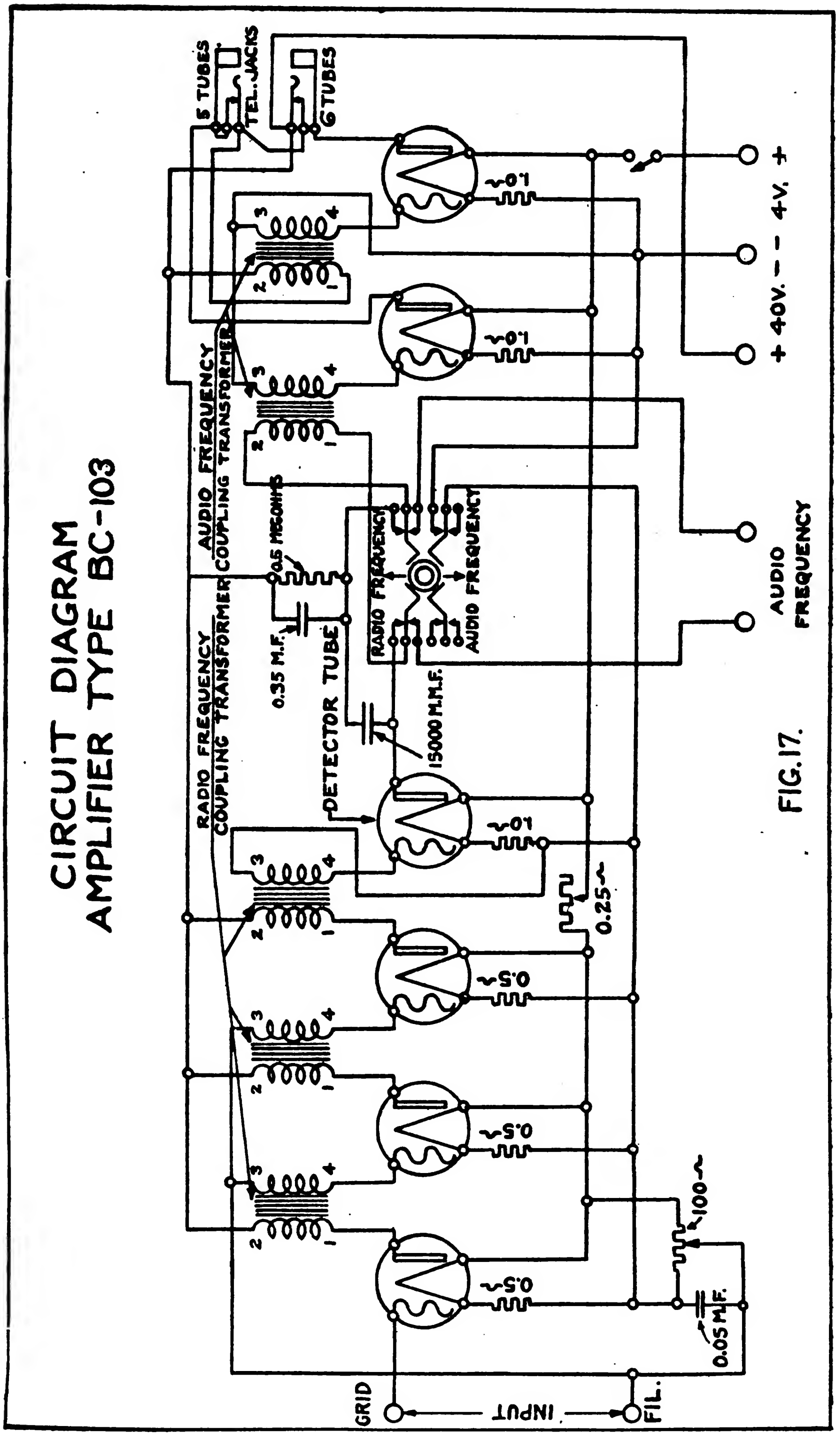
CIRCUIT DIAGRAM
AMPLIFIER TYPE BC-103
5 TUBES
TEL. JACKS
6 TUBES
1.0~
0.5~
0.25~
100~
0.05 M.F.
AUDIO FREQUENCY COUPLING TRANSFORMER
RADIO FREQUENCY COUPLING TRANSFORMER
0.5 MEGOHMS
0.35 M.F.
DETECTOR TUBE
RADIO FREQUENCY
AUDIO FREQUENCY
15000 M.M.F.
+ 40V. – – 4V. +
AUDIO FREQUENCY
GRID
INPUT
FIL.

FIG. 17.

given to the high frequency amplifiers, and in that no grid-leak and condenser are used in the grid circuit of the detector tube.

As has been stated greatest amplification is obtained when the amplifier is oscillating, but as this gives signal of poor quality, it is desirable to arrange the amplifier constants so that the amplifier is just at the point of oscillating, at which point the best readable signals are obtained. These constants will vary with different wave lengths and hence controls are necessary. In addition to the filament rheostat control found in the BC–8–A, there is a voltage divider (potentiometer) which is controlled from the panel. By means of this voltage divider, the average potential of the grid may be varied. Varying the potential of the grid varies the plate resistance of the tubes and hence, within limits, it is possible by this means to bring the amplifier to the point of oscillating.

The transformer in the plate circuit of the third radio frequency amplifier tube has its secondary connected directly between the grid and filament of the detector tube. The 1.0 ohm resistance in the detector tube filament circuit is used to place a proper negative biasing potential on the grid. The plate current for the detector tube is furnished from the 40-volt battery through the primary of an audio frequency transformer and a 0.5 megohm resistance. The resistance is by-passed for both audio and radio frequency currents by a 0.35 m. f. condenser. The primary of the audio frequency transformer is by-passed for radio frequencies by a 0.015 m. f. condenser. The effective value of plate voltages and the value of negative biasing potential on the grid are such that the value of plate current obtained is located on the greatest bend of the grid voltage-plate current curve. This causes one-half of the radio frequency cycle to be amplified more than the other half of the cycle. An audio frequency current is thereby set up having the frequency of the spark signal or the heterodyne beat note signal.

54. Heterodyne set box, type BC–104.—In order to cause a tube to oscillate it is necessary to couple the grid and plate circuit in such a manner that the transfer of energy from the plate to the grid circuit will compensate for all losses in the grid circuit. Inductive coupling is used for this purpose in the BC–104, whose circuit diagram is shown in figure 18. Frequency of oscillation is determined in the heterodyne by the grid circuit, which contains a variable air condenser, C_1, and an inductance variable in two steps. The condenser, C_2, is placed across the terminals of the plate battery and furnishes a by-pass for the oscillations in the plate circuit. It is to be noted that the coil transferring energy to the output circuit is the grid coil. The heterodyne is so designed that oscillation will be started as soon as the filament current is turned on. The oscillations are

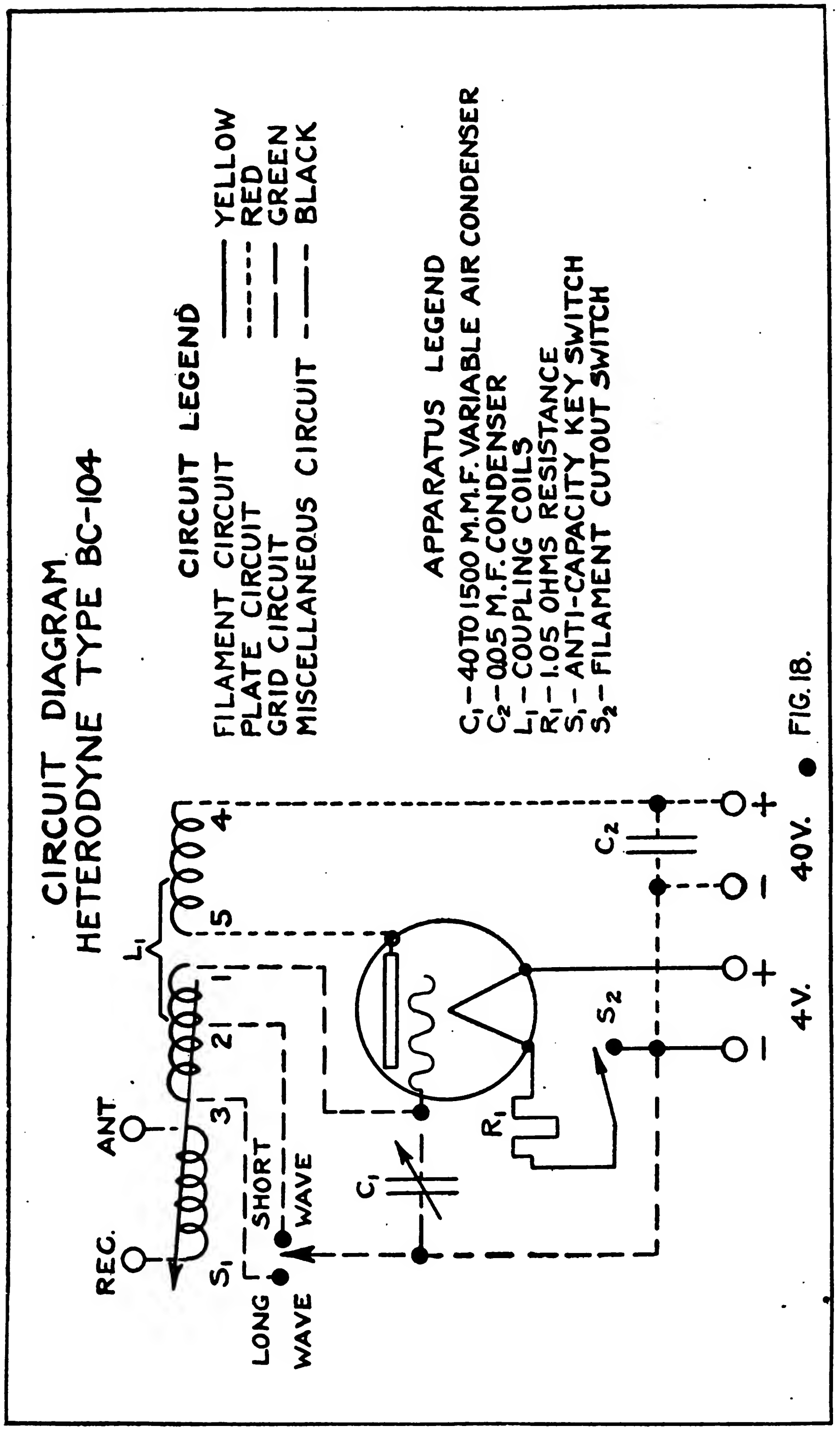
CIRCUIT DIAGRAM
HETERODYNE TYPE BC-104
CIRCUIT LEGEND
FILAMENT CIRCUIT —— YELLOW
PLATE CIRCUIT - - - - RED
GRID CIRCUIT — — — GREEN
MISCELLANEOUS CIRCUIT -—-— BLACK
APPARATUS LEGEND
C1 – 40 TO 1500 M.M.F. VARIABLE AIR CONDENSER
C2 – 0.05 M.F. CONDENSER
L1 – COUPLING COILS
R1 – 1.05 OHMS RESISTANCE
S1 – ANTI-CAPACITY KEY SWITCH
S2 – FILAMENT CUTOUT SWITCH
REC.
ANT
S1
LONG WAVE
SHORT WAVE
L1
1
2
3
4
5
C1
R1
S2
C2
4V.
40V.
+
−

FIG. 18.

strong enough to persist under any operating conditions that may occur in the receiving antenna circuit.

As is well known, the heterodyne method of reception consists of generating local oscillations, which, added to the incoming signal oscillation, produces a beat note which may be made of audible frequency. The local oscillation added to the incoming oscillation has the effect of amplifying it. The amplitude of the local amplification which produces the greatest effective amplification depends upon the amplitude of the incoming signal and to some extent upon the design of the receiving and detecting apparatus. The amplitude of the local oscillation which is added to the received oscillation may be varied by varying the coupling between the heterodyne and receiving circuits. A control handle is provided for this purpose.

In addition to the many advantages possessed by the beat method of reception, the method of using a heterodyne for this purpose has the following advantages over the method which uses an autodyne: In using an autodyne there must be a close reactance coupling between the grid and plate circuits of the autodyne tube, and hence interfering signals, especially spark, will be amplified. In using an autodyne it must be slightly detuned in order to produce beats of desired frequency; this weakens the incoming oscillations. A heterodyne can also be calibrated and used as a wave meter.

SECTION XI.

PARTS LIST OF SETS.

55. Equipments in complete sets.—The equipments forming the complete sets of the amplifiers and heterodynes described in this pamphlet are as follows:

Set T. P. S. receiving, type SCR–72:
- Equipment, type GD–3.
- Equipment, type PE–12.
- Equipment, type RC–3.

Set T. P. S. receiving, type SCR–72–B:
- Equipment, type GD–3–A.
- Equipment, type PE–10.
- Equipment, type RC–3–B.

Set low frequency amplifier, type SCR–121:
- Equipment, type PE–10.
- Equipment, type RC–11.

Set low frequency amplifier, type SCR–121–B:
- Power equipment, type PE–38.
- Amplifier equipment, type RC–11–B.

Amplifier set, type SCR–144:
- Power equipment, type PE–38.
- Amplifier equipment, type RE–24.

Amplifier set, type SCR–145:
  Power equipment, type PE–38.
  Amplifier equipment, type RE–25.
Heterodyne set, type SCR–146:
  Power equipment, type PE–38.
  Heterodyne equipment, type RE–26.
Amplifier set, type SCR–147:
  Power equipment, type PE–38.
  Amplifier equipment, type RC–3–A.
Amplifier set, type SCR–148:
  Power equipment, type PE–38.
  Amplifier equipment, type RE–27.
Amplifier set, type SCR–149:
  Power equipment, type PE–38.
  Amplifier equipment, type RE–28.

56. Parts list of equipments.—The equipments listed in the paragraph above comprise parts as follows:

Power equipment, type PE–10:
  Battery, type BB–14 (3)—1 in use, 2 spare.
Power equipment, type PE–12:
  Battery, type BB–2 (2)—1 in use, 1 spare.
Power equipment, type PE–38:
  Battery, type BB–28 (2)—1 in use, 1 spare.
Radio equipment, type RC–3:
  Battery, type BA–2 (4)—2 in use, 2 spare.
  Case, type CS–2 (1).
  Cord, type CD–22 (1).
  Headset, type P–11 (2).
  Radio Communication Pamphlet No. 9 (1).
  Set box, type BC–17 (1).
  Tube, type VT–1 (4)—2 in use, 2 spare.
Amplifier equipment, type RC–3–A:
  Battery, type BA–2 (4)—2 in use, 2 spare.
  Case, type CS–2 (1).
  Cord, type CD–50 (1). (Equipped with terminal type TM–12–A instead of TM–12.)
  Cord, type CD–56 (1).
  Headset, type P–11 (2).
  Radio Communication Pamphlet No. 9 (1).
  Set box, type BC–17 (1).
  Tube, type VT–1 (4)—2 in use, 2 spare.
Radio equipment, type RC–3–B:
  Bag, type BG–13 (1).
  Battery, type BA–2 (4)—2 in use, 2 spare.
  Compass, watch, luminous dial (1).
  Cord, type CD–40 (2)—1 in use, 1 spare.
  Cord, type CD–56 (1).
  Headset, type P–11 (2).
  Pliers, 6-inch combination (1).
  Radio Communication Pamphlet No. 9 (1).
  Screwdriver, 1½-inch blade, ⅛-inch tip (1).

Radio equipment, type RC-3-B—Continued.
- Set box, type BC-44 (1).
- Tape, friction (¼ pound).
- Tube, type VT-1 (4)—2 in use, 2 spare.
- Voltmeter, type I-10 (1).

Radio equipment, type RC-11:
- Battery, type BA-2 (4)—2 in use, 2 spare.
- Cord, type CD-40 (2)—1 in use, 1 spare.
- Cord, type CD-56 (1).
- Headset, type P-11 (2).
- Radio Communication Pamphlet No. 9 (1).
- Set box, amplifier, type BC-44-A (1).
- Tube, type VT-1 (4)—2 in use, 2 spare.

Amplifier equipment, type RC-11-B:
- Battery, type BA-2 (4)—2 in use, 2 spare.
- Cord, type CD-50 (2)—1 in use, 1 spare. (Equipped with terminal, type TM-12-A instead of TM-12.)
- Cord, type CD-56 (1).
- Headset, type P-11 (2).
- Radio Communication Pamphlet No. 9 (1).
- Set box, amplifier, type BC-44-A (1).
- Tube, type VT-1 (4)—2 in use, 2 spare.

Amplifier equipment, type RE-24:
- Battery, type BA-2 or BA-8 (4)—2 in use, 2 spare.
- Cord, type CD-50 (1). (Equipped with terminal, type TM-12-A instead of TM-12.)
- Headset, type P-11 (2).
- Radio Communication Pamphlet No. 9 (1).
- Set box, amplifier, type BC-8-A (1).
- Tubes, type VT-1 (12)—6 in use, 6 spare.

Amplifier equipment, type RE-25:
- Battery, type BA-2 or BA-8 (4)—2 in use, 2 spare.
- Cord, type CD-42 (1).
- Cord, type CD-50 (1). (Equipped with terminal, type TM-12-A instead of TM-12.)
- Headset, type P-11 (2).
- Radio Communication Pamphlet No. 9 (1).
- Set box, amplifier, type BC-103 (1).
- Tubes, type VT-1 (12)—6 in use, 6 spare.

Heterodyne equipment, type RE-26:
- Battery, type BA-2 or BA-8 (4)—2 in use, 2 spare.
- Cord, type CD-50 (1). (Equipped with terminal, type TM-12-A instead of TM-12.)
- Radio Communication Pamphlet No. 9 (1).
- Set box, heterodyne, type BC-104 (1).
- Tubes, type VT-1 (2)—1 in use, 1 spare.

Amplifier equipment, type RE-27:
- Bag, type BG-13 (1).
- Battery, type BA-2 (4)—2 in use, 2 spare.
- Cord, type CD-50 (1). (Equipped with terminal, type TM-12-A instead of TM-12.)
- Cord, type CD-56 (1).
- Headset, type P-11 (2).

Amplifier equipment, type RE–27—Continued.
- Radio Communication Pamphlet No. 9 (1).
- Set box, amplifier, type BC–44 (1).
- Tubes, type VT–1 (4)—2 in use, 2 spare.

Amplifier equipment, type RE–28:
- Bag, type BG–45 (1).
- Battery, type BA–2 (4)—2 in use, 2 spare.
- Case, type CS–20 (1).
- Cord, type CD–50 (1). (Equipped with terminal, type TM–12–A instead of TM–12.)
- Cord, type CD–56 (1).
- Headset, type P–11 (2).
- Radio Communication Pamphlet No. 9 (1).
- Set box, amplifier, type BC–101 (1).
- Tubes, type VT–1 (6)—3 in use, 3 spare.

Ground equipment, type GD–3 (used in T. P. S. sets):
- Bag, type BG–3 (1).
- Drum, type DR–3 (2).
- Hammer, 2 lb. cross-peen (1).
- Reel, type RL–6 (1).
- Stake, type GP–4, or GP–6, or GP–14 (12).
- Wire, type W–4 (1,000 feet).
- Wire, type W–5 (60 feet).

Ground equipment, type GD–3–A (used in T. P. S. sets):
- Bag, type BG–8 (1).
- Drum, type DR–3 (2).
- Hammer, 2 lb. cross-peen (1).
- Reel, type RL–6 (1).
- Stake, type GP–6 (12).
- Wire, type W–4 (1,000 feet).
- Wire, type W–5 (60 feet).

SIGNAL CORPS PAMPHLETS.

(Corrected to February, 1922.)

RADIO COMMUNICATION PAMPHLETS.

(Formerly designated Radio Pamphlets.)

No.

1. Elementary Principles of Radio Telegraphy and Telephony (edition of 4–28–21) (W. D. D. No. 1064).
2. Antenna Systems.
3. Radio Receiving Sets (SCR–54 and SCR–54–A) and Vacuum Tube Detector Equipment (Type DT–3–A).
5. Airplane Radio Telegraph Transmitting Sets (SCR–65 and SCR–65–A).
9. Amplifiers and Heterodynes (W. D. D. 1092).
11. Radio Telegraph Transmitting Sets (SCR–74; SCR–74–A).
13. Airplane Radio Telegraph Transmitting Set (Type SCR–73).
14. Radio Telegraph Transmitting Set (Type SCR–69).
17. Sets, U. W. Radio Telegraph (Types SCR–79–A and SCR–99) (W. D. D. 1084).
20. Airplane Radio Telephone Sets (Types SCR–68; SCR–68–A; SCR–114; SCR–116; SCR–59; SCR–59–A; SCR–75; SCR–115).
22. Ground Radio Telephone Sets (Types SCR–67; SCR–67–A) (W. D. D. 1091).
23. U. W. Airplane Radio Telegraph Set (Type SCR–80).
24. Tank Radio Telegraph Set (Type SCR–78–A).
25. Set, Radio Telegraph (Type SCR–105) (W. D. D. 1077).
26. Sets, U. W. Radio Telegraph (Types SCR–127 and SCR–130) (W. D. D. 1056) (edition of Nov., 1921).
28. Wavemeters and Decremeters (W. D. D. 1094).
30. The Radio Mechanic and the Airplane.
40. The Principles Underlying Radio Communication (edition of May, 1921) (W. D. D. 1069).

WIRE COMMUNICATION PAMPHLETS.

(Formerly designated Electrical Engineering Pamphlets.)

1. The Buzzerphone (Type EE–1).
2. Monocord Switchboards of Units Type EE–2 and EE–2–A and Monocord Switchboard Operator's Set Type EE–64 (W. D. D. 1081).
3. Field Telephones (Types EE–3; EE–4; EE–5).
4. Laying Cable in the Forward Area (formerly designated Training Pamphlet No. 3).
6. Trench Line Construction (formerly designated Training Pamphlet No. 6–a).
7. Signal Corps Universal Test Set Type EE–65 (edition of Dec., 1921) (W. D. D. 1020).
10. Wire Axis Installation and Maintenance Within the Division (W. D. D. 1068).
11. Elements of the Automatic Telephone System (W. D. D. 1096).

TRAINING PAMPHLETS.

1. Elementary Electricity (edition of 1–1–21) (W. D. D. 1055).
2. Instructions for using the cipher device Type M–94. (W. D. D. 1097.) (For official use only.)
4. Visual Signaling.
7. Primary Batteries (formerly designated Radio Pamphlet No. 7).
8. Storage Batteries (formerly designated Radio Pamphlet No. 8).

FIELD PAMPHLETS.

1. Directions for Using the 24–CM. Signal Lamp (Type EE–7).
2. Directions for Using the 14–CM. Signal Lamp (Type EE–6).

SETS
UNDAMPED WAVE RADIO TELEGRAPH

TYPES SCR-79-A AND SCR-99

Radio Communication Pamphlet No. 17

PREPARED IN THE OFFICE OF
THE CHIEF SIGNAL OFFICER

November, 1921

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1922

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WAR DEPARTMENT,

WASHINGTON, *November 18, 1921.*

The following publication, entitled "Sets, Undamped Wave Radio Telegraph, Types SCR-79-A and SCR-99," Radio Communication Pamphlet No. 17, is published for the information and guidance of all concerned.

[062.1, A. G. O.]

BY ORDER OF THE SECRETARY OF WAR:

JOHN J. PERSHING,
General of the Armies,
Chief of Staff.

OFFICIAL:
P. C. HARRIS,
The Adjutant General.

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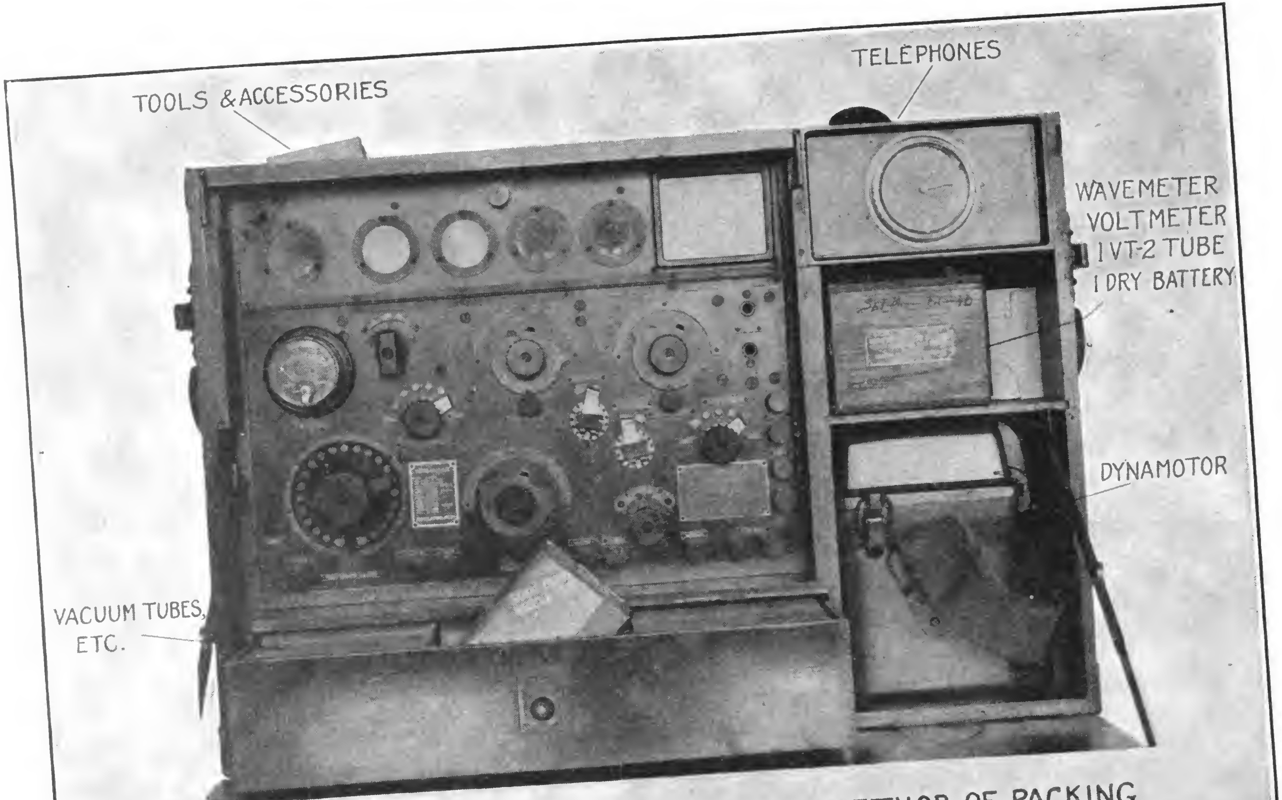

SCR-79-A CARRYING CHEST - SHOWING METHOD OF PACKING

SETS UNDAMPED WAVE RADIO TELEGRAPH, TYPES SCR-79-A and SCR-99.

SECTION I.

PURPOSE OF SETS.

1. **Purpose of sets—Ranges.**—The radio telegraph sets, Types SCR-79-A and SCR-99, are vacuum-tube sets designed for transmitting undamped wave signals and for receiving either damped or undamped signals. Both sets use in the transmitter two tubes in parallel whose circuits are inductively coupled to the oscillating circuit of the antenna, and in the receiver inductively coupled circuits with a vacuum-tube detector and a 2-stage audio-frequency amplifier. When used with the prescribed antenna, the SCR-79-A set has a continuous range of wave lengths for transmitting and receiving of from 500 to 1,100 meters. Its transmitter delivers about 10 watts to the antenna, and with this power two similar sets can communicate over a distance of about 20 miles. The SCR-99 set is very similar to the 79-A except that it is somewhat more powerful, has a range of wave lengths of from 900 to 1,900 meters, and two similar sets can communicate over a distance of about 60 miles. Both sets are intended for use at command posts or at headquarters that are equipped with ample motor or wagon transport. Frontispiece shows a 79-A set in its carrying chest.

SECTION II.

DESCRIPTION OF SETS.

2. Equipments comprising the sets.—Each set is comprised of three equipments as follows: Antenna, radio, and power. These equipments are alike in both sets except where noted below.

3. Antenna equipment, Type A–9–A.—The same antenna equipment is used with the SCR–79–A and SCR–99 sets. The essential component parts are the antenna, masts, counterpoise, ground mats, guys, and stakes. The antenna itself is a "V" with a 60-degree opening, 20 feet high, 100 feet long on each side, and with a 25-foot lead-in wire. Under some conditions, such as a limited space or for short-distance work, an inverted "L" may be used. This should be 20 feet high, 100 feet long, and with a 25-foot lead-in wire. The "V" antenna is supported on three masts, 20 feet high, each with two guys. The antenna wire is a bare stranded wire, and the lead-in is a lightly insulated wire or lamp cord. One end of both legs of the antenna wire forms the point of the "V" and to this is joined the lead-in wire. The two outer ends of the antenna and the point of the "V" are provided with strain insulators which have a snap or harness hook for fastening them to the tops of the masts. These insulators are made of an insulating material known as phenol fiber which has been thoroughly varnished and baked so as to secure high insulation. The antenna, lead-in, etc., are wound on two hand reels for convenience in storing away in transportation. The masts are of spruce and in three sections, each about 6¾ feet long, all sections being interchangeable. Each section is fitted at one end with a spike and at the other end with a steel tube that is tapered slightly to take the spike of the next section, and is pierced with three holes to take the snap hooks of the antenna insulators and guy ropes. The mast sections are carried in a carrying roll which has both a handle and a shoulder strap of nonelastic webbing. The guys are of No. 5 sash cord, 40 feet long, provided at one end with a snap or harness hook, for fastening in the holes in the steel tube of the topmast section and at the other end with a tent slide for adjusting the tension on the guy after it has been passed around the ground stake. In storing away they are wound on the same type of hand reels as the antenna. The ground stakes are of galvanized pipe, 18 inches long, and are provided with a binding post that makes it possible to use them as a ground rod if desired.

The counterpoise consists of two lengths of 150 feet of heavily insulated wire which is laid out on the ground in a "V" shape with a 60-degree opening under the antenna. In storing away they are wound on two hand reels. As an alternative for the counterpoise, three ground mats, which are of a fine copper gauze, each 13 feet long and 3 feet wide, are furnished. These have wood strips at both

ends to keep the mats flat and are provided with binding posts at both ends for convenience in making quick connections. The mats are generally rolled up for transportation and carried in the roll with the mast sections. The antenna and counterpoise wires, guys, stakes, hammer, etc., are carried in a carrying bag. The essential electrical constants of the "V" antenna are approximately: Inductance, 0.04 millihenry; capacity, 0.0004 microfarad; fundamental wave length, 240 meters; and average resistance, 50 ohms. Additional information about antennas and their theory in general can be found in Signal Corps Radio Communication Pamphlet No. 2, entitled "Antenna Systems."

4. Power equipment, Type PE–7.—*a. Battery equipment.*—The same power equipment is used with the SCR–79–A and SCR–99 sets. The essential component parts are the batteries and the dynamotor with its case. The battery furnishes current for the filaments of the transmitting and receiving vacuum tubes and for the dynamotor. It is a lead storage battery of a nonspill type; of 12 volts and 90 ampere-hour capacity, consisting of 3 units, each unit being a BB–14 battery of 4 volts. These units are connected in series by two extension cords. The connections should be made as follows: The positive or red binding post terminal of the first battery should be left free to be connected later to the operating chest (set box) by an extension cord; the negative or black binding post terminal of this battery should be connected to the positive or red terminal of the second battery; the negative or black terminal of this battery should be connected to the positive or red terminal of the third battery; and the negative or black terminal of this battery should be left free to be connected later to the operating chest (set box). If for any reason the polarity or color of the terminals can not be told, they may be identified in the BB–14 battery as follows: If the battery box is so placed that the cover opens away from the operator, the right-hand terminal in the box is positive and the left-hand is negative. The battery boxes can also be connected in series with battery cords and plugs by means of the sockets on each unit box. Both ends of the cord are provided with plugs which can fit in the socket (receptacles) only in one way, and thus no mistake can be made in the series connections. The polarity of the two receptacle terminals can be identified by the same rule as the binding posts. If neither set of battery cords is available, the necessary connections can be made as described above by any heavy wire. The connection between the battery and the operating chest (set box) is made with an extension cord. At the battery end the cord is provided with heavy lugs stamped "Plus" and "Minus." The junction of the cord and its lug is covered with rubber tubing. At the chest end it has red and

black wires, respectively, for plus and minus, that are to be connected to the binding posts on the operating chest (set box) marked, respectively, "Plus 12 V" and "Minus 12 V."

Each battery unit holds two cells in series, in hard rubber or celluloid jars, contained in a wood carrying case. If the jar is of celluloid, the wood case has two peepholes for noting the height of the electrolyte. The over-all dimensions of the two kinds of batteries (rubber and celluloid jars) differ slightly, but as an average each unit is 7½ by 8½ inches by 14 inches high, weighs about 37 pounds, and is provided with a battery carrying strap. Three 12-volt batteries (9 BB–14 units) are provided with the set. These should be assigned as follows: One in use with the set; one spare, fully charged with set and ready for immediate use; and the other under charge at the charging plant. Brief instructions by the manufacturer for the care of the battery are contained on a card in the cover of the battery box. Additional instructions on the use and maintenance of storage batteries will be found in Signal Corps Training Pamphlet No. 8, entitled "Storage Batteries."

4 *b*. *The dynamotor*, *Type DM–1*.—The dynamotor, type DM–1, is a combined motor and generator that, together with certain accessories, is contained in a cast aluminum alloy case. With the motor running light—that is, with no generator load—it takes a current of about 4 amperes at 10 or 12 volts from the storage battery. At full load the motor takes about 10 amperes at 10 or 12 volts, and the generator delivers about one-sixth ampere (167 milliamperes) at 300 to 350 volts to the plate circuit of the vacuum tubes of the transmitter. The motor input is therefore about 120 watts, the generator output about 50 watts, and the over-all efficiency is between 40 and 50 per cent. The machine is a converter from a low to a high direct-current voltage. It has separate motor and generator armature windings and commutators mounted on the same shaft, revolving in a single common magnetic field. The speed of the machine is 2,550 R. P. M. (revolutions per minute). The motor end is marked but can still further be identified by the heavier wires at the brushes. Generator ends are marked on the end shield. The necessary wiring from the motor and generator is brought up onto a bakelite panel that carries a fuse block, with 15-ampere fuse wire, a switch in the motor leads, extension cords, oiling holes, etc. Spare fuse wire is wound on a small spool in the cover of the box. On the panel the motor terminals are marked "10 Volts," "Plus," and "Minus." An extension cord is provided to connect them to the binding posts on the operating chest (set box) marked, respectively, "Plus 10 V" and "Minus 10 V." The generator terminals are marked "300 Volts," "Plus," and "Minus." An extension cord is provided to

connect them to the binding posts on the operating chest (set box) marked, respectively, "Plus 300 V" and "Minus 300 V." In both cords the red wire is positive and the black is negative. Both cords are permanently fastened to the dynamotor terminals and are to be stored away on top of the panel. The polarity of the dynamotor terminals is marked on the panel, but in both cases they can be identified by noting that with the cover of the case opened away from the operator the right-hand post of each pair is positive. The dynamotor is secured in place in the lower part of its carrying case by two heavy machine screws through the bottom. The approximate over-all dimensions are 7 by 11 inches by 9 inches high, its weight is about 24 pounds, and it is provided with a carrying strap.

5. Radio equipment for SCR–79–A and SCR–99.—The radio equipment of these sets is mounted in an operating chest (set box) shown in figure 1.

The radio equipment of the SCR–79–A, RE–5–A, is mounted in the operating chest (set box), Type BC–32–A, and the radio equipment of the 99, RE–7, is mounted in the operating chest (set box), Type BC–45. These operating chests, together with auxiliary equipment, are all carried in a carrying chest, Type BC–43. Although the operating chests are removable from their carrying chests, in general they should be left inside. The auxiliary parts carried in the operating chest are the telephones, key, wavemeter, voltmeter, clock, various extension cords, tools, and spare parts, including tubes. The dynamotor is also carried in this chest. There follows a more detailed description of the principal parts of the radio apparatus and also a description of the panel clock carried in the chest.

5 *a. Transmitter.*—The transmitting set in the SCR–79–A and SCR–99 is practically the same except for the range of wave lengths. It consists of vacuum-tube oscillating circuits with fixed inductive coupling between the tube and the antenna circuits. The transmitter inductances have been so designated that with standard antenna the correct couplings are automatically secured over the entire range of wave length when the inductances corresponding to a given wave length are in use. The wave length is determined by the electrical constants of the antenna circuit, and *not* by those of the *tube circuit*, being adjustable by a variable inductance L_3 and a variable condenser C_5 in the antenna circuit. When the key is closed power at about 350 direct-current volts from the dynamotor is supplied to the plate circuits of the tubes and the antenna circuit immediately starts oscillating. Thus the energy is radiated only when the key is pressed and there is no "back wave" as in some arc transmitters. The current in the transmitting-tube filaments is adjustable by a rheostat.

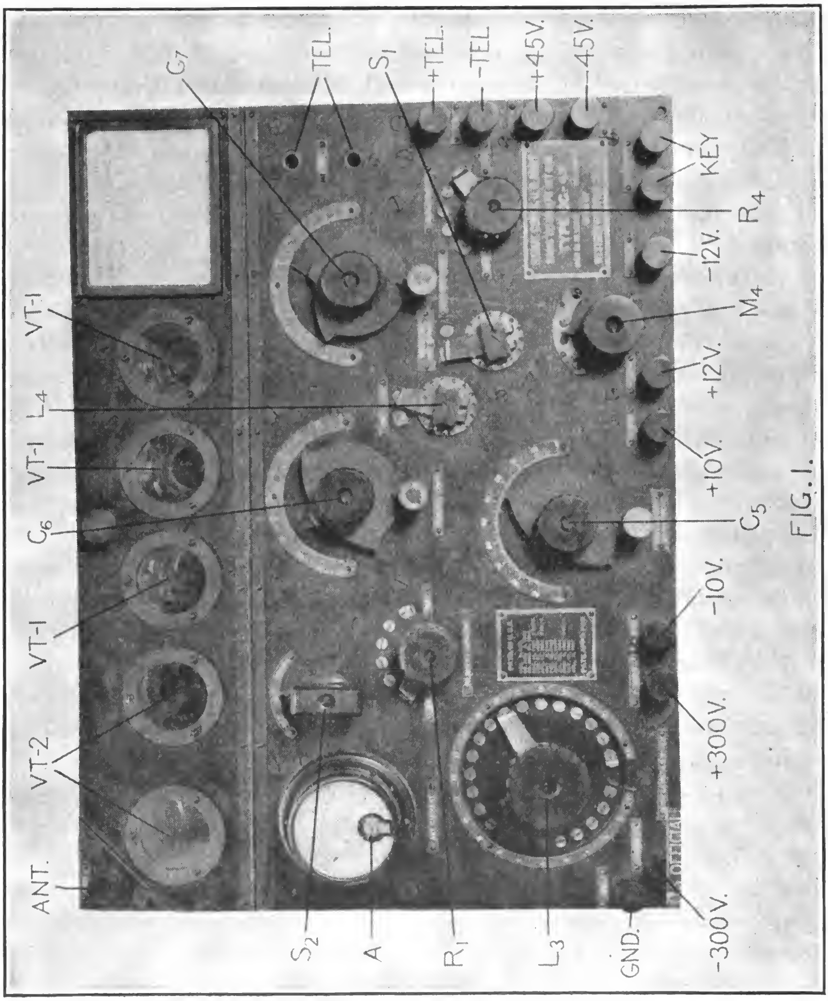
ANT.
VT-2
VT-1
C_6
VT-1
L_4
VT-1
G_7
TEL.
S_1
+TEL.
-TEL
+45V.
-45V.
KEY
R_4
-12V.
M_4
+12V.
+10V.
C_5
-10V.
+300V.
-300V.
GND.
L_3
R_1
A
S_2

FIG. 1.

Each figure in this pamphlet has the identical parts marked the same.

In Figure 1 the controls bear the same legend as the actual parts. The legend is as follows:

A	Antenna ammeter.
ANT	Antenna binding post.
C_1	High-frequency by-pass condenser across dynamotor leads.
C_2	Grid leak condenser for VT–2 tubes.
C_3	Plate coil shunting condenser.
C_4	Ground circuit condenser.
C_5	Transmitter antenna tuning condenser.
C_6	Receiver antenna tuning condenser.
C_7	Receiver secondary tuning condenser.
C_8	High-frequency by-pass condenser across the primary of the first intervalve transformer.
C_9	Audio-frequency by-pass condenser across the resistance in the detector tube plate circuit.
Fil. Bat.	12-volt storage battery for heating filaments of VT–1 and VT–2 tubes.
GND	Ground binding post.
H. P. Bat.	45-volt high potential battery for plate circuits of VT–1 tubes.
L_1	Grid coil for VT–2 tubes.
L_2	Plate coil for VT–2 tubes.
L_3	Transmitter antenna tuning inductance.
L_4	Receiver antenna tuning inductance.
L_5	Reaction or " feed-back " coil.
L_6	Receiver secondary circuit coil.
M_1	Fixed coupling between VT–2 grid coil, L_1, and antenna coil, L_3.
M_2	Fixed coupling between VT–2 plate coil, L_2, and antenna coil, L_3.
M_3	Fixed coupling between reaction coil, L_5, and primary receiving coil, L_6.
M_4	Variable coupling between primary and secondary receiving circuits.
R_1	Variable filament resistance for VT–2 tubes.
R_2	Grid leak resistance for VT–2 tubes.
R_3	Series filament resistance for VT–1 tubes.
R_4	Shunt resistance across primary of first intervalve transformer for variations in amplification.
R_5	High resistance in detector tube plate circuit for adjustment to best detecting point on characteristic curve.
R_6	Series filament resistance for VT–2 tubes.
RFC	Radio frequency choke coils in dynamotor leads.
S_1	Switch to change from spark to tube reception, and vice versa.
S_2	Switch to change from transmitting to receiving, and vice versa.
T_1	Intervalve iron core transformer between detector tube and first amplifying tube.
T_2	Intervalve iron core transformer between first and second amplifying tubes.
TEL	High impedance telephone receivers.
VT–1	Receiving vacuum tubes for detector and audio-frequency amplifiers.
VT–2	Transmitting vacuum tubes for developing oscillations in transmitting antenna.

5 *b*. *Receiver*.—The receiver set in the SCR–79–A and SCR–99 is practically the same except for the range of wave lengths. It is an inductively coupled set with a vacuum-tube detector and a 2-stage audio-frequency amplifier, arranged for both damped wave and undamped wave reception. In the antenna circuit an inductance, L_4, with two taps, one for short waves, "SW," and the other for long waves, "LW," is connected in series with a variable condenser C_6 to change from short wave to long wave. In the secondary circuit a fixed inductance and a variable condenser (C_7) are connected in series to form a local resonant circuit with leads from its terminals to the detector. A "feed-back" or "reaction" coil can be put into circuit by the 2-point switch S_1, depending on whether undamped or damped signals are to be received. The coupling between the primary and secondary circuits is controlled by a two-position switch (M_4). In some cases the full amplification given by the tubes is not desired and it may be reduced by the switch R_4, which connects resistance shunts across the primary circuit of the first amplifier transformer. There is no adjustment for the filament current of the receiver tubes. Figures 2 and 3 show interior views of the set.

5 *c*. *Vacuum tubes*.—Two types of 3-electrode vacuum tubes are furnished with each set; one, Type VT–2, for the transmitter, and the other, Type VT–1, for the receiver. The transmitter type, VT–2, is spherical, and the receiver type, VT–1, cylindrical; and in some cases the type number is also marked on the base or on the glass. The bases and sockets for the two types are identical except for the position of a pin in the base and a slot in the socket, which are so arranged that only the right tube can be put in the right socket. The VT–2 filament uses about 1.35 amperes at about 7 volts, and as two tubes are connected in parallel, the total current is 2.7 amperes. If the 12 volts of the standard battery were applied directly to the filaments, too much current would flow and hence a small fixed resistance R_6 of about 1.8 ohms, is connected in series in one lead to each filament, and in addition, for fine adjustment and to compensate for a drop in the voltage as the battery runs down, there is inserted in series in one battery lead another small resistance that is variable by a 6-point dial switch, R_1. In transmitting, the 12-volt battery furnishes the current for the filaments as well as that for running the dynamotor with its generator load of plate currents. The receiving tubes (VT–1) must be burned only at a dull reddish-yellow heat, as in the case of the VT–2 tubes, otherwise their normal life of 500 hours will be seriously shortened. The VT–1 filament uses about 1.1 amperes at about 3.6 volts, and in order to be able to use the 12-volt standard battery the filaments of the three tubes are connected in series and in addition there is a small fixed resistance R_3 of about 1.05 ohms, in the negative lead to each filament. There is no variable resistance in

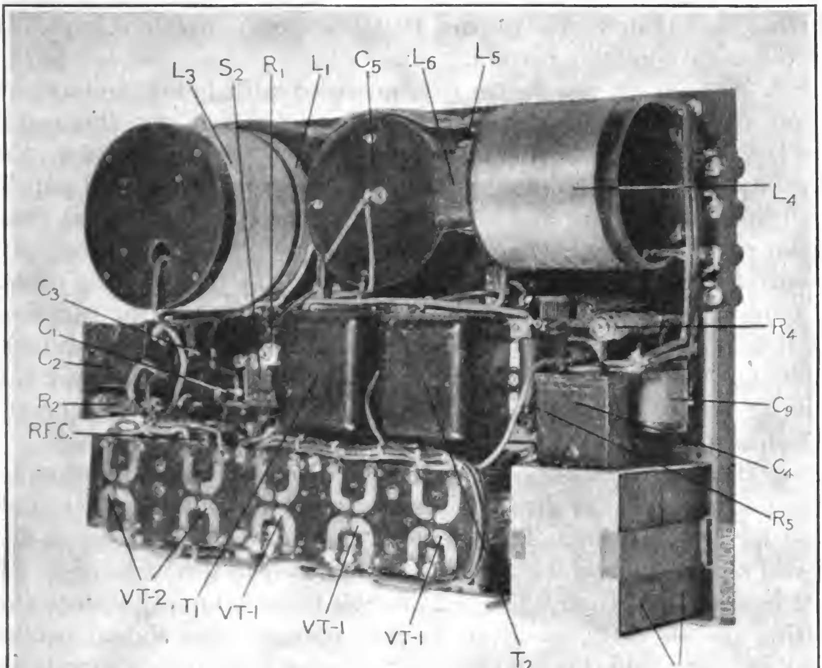
L3
S2
R1
L1
C5
L6
L5
L4
C3
C1
C2
R2
R.F.C.
R4
C9
C4
R5
VT-2, T1
VT-1
VT-1
VT-1
T2
H.P.BAT.

FIG. 2.

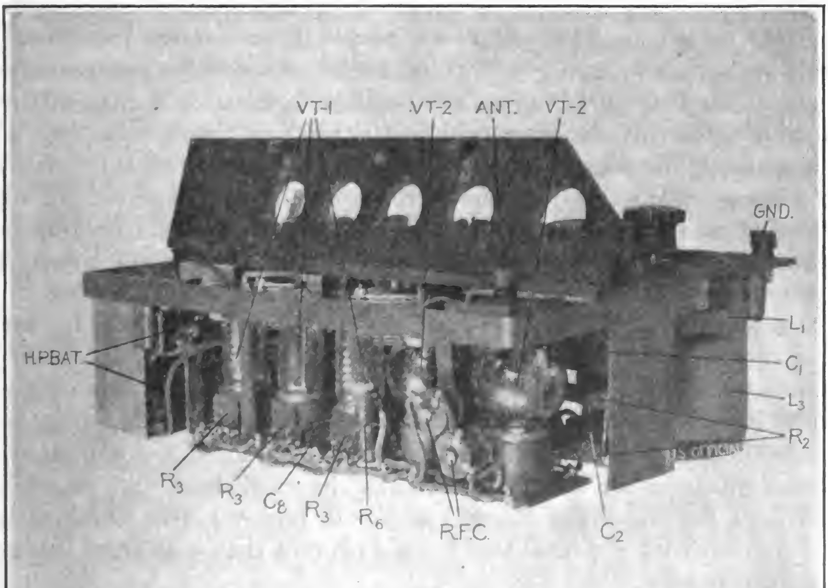
VT-1
VT-2
ANT.
VT-2
GND.
L1
C1
L3
R2
H.P.BAT.
R3
R3
C8
R3
R6
R.F.C.
C2

FIG. 3.

circuit. The plate circuit of each receiving tube takes only a small current, less than a milliampere (0.001 ampere), which is supplied by the high potential battery.

5 *d. Key.*—This is a Morse key, provided with heavy contacts of silver. On account of its high conductivity for heat, etc., this metal has the property of quenching an arc and hence tends to reduce the sparking in much the same way that the spark in a quenched gap is quenched. It is connected in series in one lead in the 300-volt generator circuit of the dynamotor and thus directly controls the supply of direct-current power to the plate circuit of the transmitting tubes. A brass plate is provided on the inside of the cover of the carrying chest for mounting the key when the cover is used as an operator's table, and the 1½-foot extension cord should be used to connect the binding posts of the key to the "KEY" binding posts on the operating chest (set box).

5 *e. Antenna ammeter.*—The ammeter used is of the thermocouple type and is connected directly in series with the antenna when it is used for transmitting. The ammeter used in the SCR–99 set is designed to read a greater current than that used in the SCR–79–A set and is graduated from 0 to 1. Although there is an adjustment for setting the ammeter needle to its zero position, this should not be used, as in the field it is not necessary to know the absolute current in the antenna. The ammeter is used to show the relative strength of current in the antenna and to show that the set is oscillating properly. If the set does not oscillate, there will be no antenna current.

5 *f. Voltmeter.*—This meter is a 2-scale direct-current instrument with scales 0 to 10, and 0 to 50 volts, and is provided for the measurement of the battery voltage. The positive terminal is the tip of the flexible lead which is connected to the binding post on the top of the meter. The negative terminal is the brass point on the bottom of the case. The meter normally reads on the 50-volt scale, but by pressing on the push button on the back of the base the reading is transferred to the 10-volt scale. There is no adjustment for any zero error of the needle, as such accuracy is not needed in field service.

5 *g. Wave-length switch.*—This is a 23-point dial switch, L_3, for making large step adjustments in antenna inductances of the transmitting circuits. Exact adjustment of wave lengths is made by the shunt condenser, C_5. In using the switch, care must be taken *not* to allow the switch point to rest on two contacts, as this would short-circuit turns in the antenna coil, cause losses therein, and possibly burn out the windings. It will be noted, however, that the switch is provided with a ratchet that *should* prevent the point from bridging two contacts.

5 *h. Table of wave lengths.*—A table for recording the receiver wave lengths in meters and the position of the secondary circuit condenser in degrees is provided in the upper right corner of the panel of the

operating chest (set box). The method of obtaining this data is given under "Wavemeter," paragraph 5 *k*, and by its use it is possible to pick up very easily a station sending on a known wave length.

5 *i*. *Amplification switch.*—This is a 5-point switch for the control of the amplification of the receiver signals, from the full amplification of two stages at "Max." to slightly more than one stage at "Min." The variation in amplification is obtained by shunting the primary or input winding of the first intervalve audio-frequency transformer by a variable resistance, R_4. At "Max." the resistance is cut out of circuit so that all the audio-frequency current from the plate circuit of the detector tube is allowed to pass through the windings; at "Min." a *low* resistance is shunted across the windings so that most of the current is diverted from them and the resulting amplification is much reduced; and at immediate steps the amplification is somewhere between these stages.

5 *j*. *Receiver-transmitter switch.*—This switch, S_2, is a 3-throw, 2-pole switch with positions marked "Rec.," "Off," and "Trans." In the "Trans." position the circuits are connected as shown in figures 4 and 5, whereby the VT–2 filaments are lighted, and if the switch on the dynamotor panel is closed, the dynamotor is started and the circuits are ready for adjustment. It is to be noted that there is no motor starting resistance or box in circuit, but this is not necessary, as the motor is only a fraction of a horsepower in size and the starting current is not large. Whenever the dynamotor is to be stopped, it should be done by throwing the switch to the "Off" position rather than to open the switch on the dynamotor panel. The VT–2 filament current is adjusted to its correct value when the dynamotor is running; if its switch is now opened and the load of the dynamotor taken off the battery, the voltage across the battery will rise. This rise in voltage may so increase the filament current as to burn out the filament or seriously injure its life by the rush of excessive current. In the "Rec." position the circuits are connected as shown in figures 4 and 6. The VT–1 filaments are lighted, and the circuits are ready for adjustment. In the "Off" position the antenna and ground wires are simply disconnected from the rest of the circuits but the antenna is *not* grounded direct to the ground, as is sometimes the case in such a switch. For this reason when the set is not in use the antenna and ground wires should be disconnected from the set and the antenna put to ground. The complete circuits of the sets are shown in figure 4.

5 *k*. *Wavemeter.*—Wavemeter, Type SCR–95, is furnished for use with the SCR–79–A set and Type SCR–111 for use with the SCR–99 set. Each has the same range of wave lengths as its set, i. e., 500–1,100 meters, or 900–1,900 meters, and can be used to measure both transmitter and receiver signals. They are of the type that uses for the essential elements of its resonant circuit a fixed (mica) condenser as the capacity, in series with a variometer as the inductance,

COMPLETE CIRCUIT

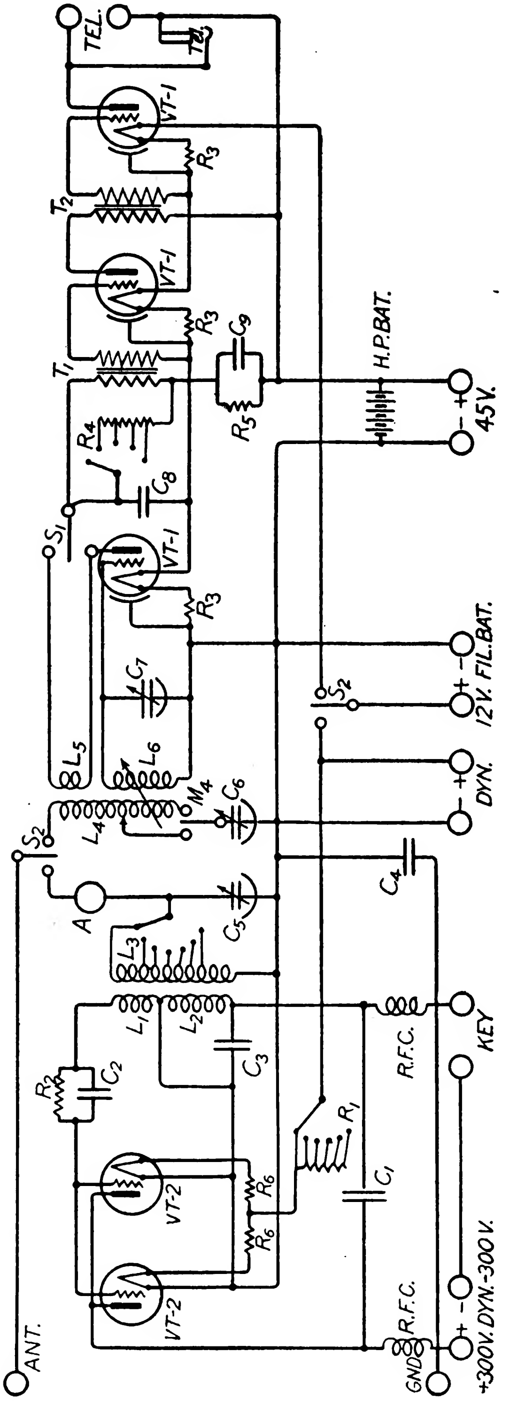

FIG. 4.

and a miniature (flashlight) lamp, Type LM–4, as the means of indicating resonance. One dry cell, Type BA–4, of 1.5 volts, about 3 inches long and 1¼ inches in diameter, is provided for lighting the filament of the lamp, also for operating a buzzer. The wavemeter has one scale for direct reading of wave length and another one of degrees. There is a 3-point switch which, when on contact C, puts the lamp into circuit; on B puts the buzzer into circuit for receiver signals; and on A disconnects the battery. Although the battery is disconnected when the switch is on the A contact, yet the meter is operative for strong transmitter signals, as its circuit is still complete. A small, adjustable carbon rheostat is placed in the lamp circuit to keep the filament burning at a dull red where it is most sensitive in showing small changes in current caused by the reception of signals. The front of the box is hinged so as to provide access to the inside of the meter for replacing the battery, adjusting the buzzer, etc. When the meter is held with the scale horizontal, the plane of the fixed variometer coil is vertical and parallel with the rear of the box. It is often necessary to take note of the position of this coil in obtaining coupling with the circuit under measurement. Brief instructions for the use of the meter are contained on a card inside the front cover of the box, as follows: "To measure wave length, set switch on 'C' and adjust carbon resistance until lamp glows a dull red. Couple wavemeter by holding near inductance coil of sending set. Rotate dial slowly until lamp lights to maximum brilliancy, when wave length is indicated on wavemeter dial. To set receiver for given wave length, set switch on 'B,' adjust buzzer to give a clear note, and turn dial to desired wave length. Couple as above and tune receiver until buzzer is heard loudest in phones. Caution: Replace battery when it fails to operate buzzer or lamp. When meter is not in use, leave switch on 'A' only." For further information concerning wavemeter, see Radio Communication Pamphlet No. 21 or 28. See also paragraph 11, this pamphlet.

5 *l. Clock.*—The clock is an 8-day Waltham automobile clock that is mounted flush with its panel. To wind or set the clock, press in on the knurled metal frame carrying the plate-glass front and turn it counterclockwise until the clock springs out from its panel. This will generally occur when the "1" or "2" hour mark is at the top. It is then held by a universal joint that permits access to the key that lies in a slot on the top of the clock. To wind, raise the key and turn it clockwise. To set the clock, pull up on the key until a sharp click is heard, in which case the key is engaged with the gears that will now turn the hands. After setting, be sure to push the key down until the sharp click is again heard. After winding or setting the hands, put the key back flat in its slot and return the

clock to its panel by inserting it with the "1" or "2" hour mark at the top and turning clockwise until the "12" hour mark is at the top. There is no adjustment provided for "faster" or "slower" regulation. Under ordinary circumstances the clock should never be removed from the panel, but when necessary this can be done by unscrewing the narrow ring at the back of the clock, which is prevented from working loose by a heavy spring washer.

SECTION III.

SETTING UP AND OPERATION OF SETS.

6. Setting up the antenna.—The antenna can be installed for either of two purposes: (1) general use and (2) directional use. For the former the orientation of the wire is not important, but for the latter the point of the "V" should be directed toward the other station.

Stretch out the antenna wires on the ground with an opening of about 60 degrees. Couple three mast sections together for each mast and lay them on the ground alongside the wire and in the same straight line with it. Attach the antenna insulators to the tops of the three masts by means of the snap hooks and also attach two guys to each mast. Drive two ground stakes near each mast about 20 feet beyond the end of the wire so that the guys will lie at an angle of about 45 degrees with the line of the wire. Having raised the mast at the point of the V, raise the other mast tops gradually by using a light strain on the guys and, keeping the bottom ends of the masts on the ground, move them toward the points where they are to be when the mast is in the vertical position. Pass the guys around the ground stakes and take up the slack with the tent slides. If necessary, straighten up the masts and tighten the guys so that the antenna wires are nearly horizontal. Care should be taken in raising the masts to keep them in the prolongation of the antenna wires, as then there will be little or no stress tending to bend the masts.

7. Installing the counterpoise.—For general use the two counterpoise wires should be laid out on the ground under the antenna with the point of the "V" at the "GND" binding post of the operating chest (set box). If four counterpoise wires are available they should be laid out as two "Vs" with the points together, one under the antenna and the other with its free ends opening out toward the other station.

For directional use the two wires should be laid out as a "V" with the point at the "GND" post as before and with the free ends opening out toward the other station.

8. Installing the ground mat.—As an alternative for the counterpoise, three ground mats are furnished that should be connected to the "GND" post of the operating chest. These mats should be buried under a few inches of earth, which should be well packed down so as to get good contact with all the wires. Under some circumstances the spare ground stakes should be used as an additional ground, and the other ground wires or plates connected to the chest. The ground connection should preferably be made where it is wet, but in each case use whichever apparatus will give the largest reading on the antenna ammeter.

9. Installing the operating chest.—Set up the operating chest on a dry place under the point of the "V" of the antenna. Before making any connection to the chest be sure that the switch, S_2, is in the "Off" position, and that the high potential battery, 2 units Type BA–2, in series, is in its compartment. If there is no battery, an external battery of 45 volts may be connected to the binding posts marked "Plus 45 V" and "Minus 45 V," being sure that the positive or red-wire terminal is connected to the upper and positive post and the negative or black wire terminal to the lower and negative post. These connections must be correctly made, as otherwise the receiver will be inoperative. If the standard high potential battery is available, it is preferable to install it in place as follows: Take out the right-hand VT–1 tube so as to give free access to the battery compartment. Put one BA–2 battery in place with the line of its terminals vertical and to the left, connecting them to the Fahnestock clips on the small panel by passing the lead wires behind the panel; put the other battery similarly in place except for passing the leads in front of the panel; the positive or red-wire terminal of each battery must be connected to the clips on the red part of the panel and the negative or black-wire terminals to the clips on the black part of the panel; if these connections are correctly made the two batteries will be in series, with the positive terminal connected to the plate circuit of the last tube through the telephone receivers and with the negative terminal to the ground.

Connect the antenna and ground wires respectively to the two binding posts marked "ANT" and "GND." Make the other connections to the binding posts as shown by their name plates on the chest, taking care that the polarity is correct in the case of both sets of dynamotor terminals and of the storage battery. (See par. 4.) It is specially necessary that the high potential side of the dynamotor be correctly connected, as otherwise the transmitter will be inoperative. Be sure to connect the battery leads first to the chest and then to the battery, as otherwise the battery may be short-cir-

cuited by the other terminals of the cord being in contact. If the telephone is not provided with the standard plug, connections can be made by the telephone cord to the posts marked "TEL," making sure that the green tracer wire is connected to the "Plus" post and the red tracer wire to the "Negative" post. If for any reason the two wires can not be identified, the correct polarity of the connections must be found by trial, using faint signals which may be generated by the wavemeter with the set. *Close the switch* on the dynamotor panel and then turn the switch S_2 to "REC." or "TRANS." as desired. The set is now ready for tuning either the receiver or transmitter.

10. How to receive.—Turn the switch "S_2" to the "Rec." position and the three VT–1 filaments should light; if they do not, there is either a bad battery contact or one or more broken or burnt-out filaments. Examine the battery connections and the filaments and correct the difficulty. In a few cases the filament pins in the base of the tube may not make good contact with the springs of the socket, but generally this can be remedied simply by taking the tubes out and putting them back in the sockets. It must be remembered that the three filaments are in series in the battery circuit and that one break in the circuit will prevent all filaments from lighting. If signals are to be received from another SCR–79–A or 99 set or from any undamped wave source, set the switch "S_1" on the "Het." position and the switch "R_4" on the "Min." position. If the wave length is known, set the secondary receiver condenser handle, "C_7," at the reading corresponding to this wave length as shown in the "Wave-length table" in the upper right-hand corner of the panel of the operating chest (set box). Set the switch "L_4" on the short-wave position, "SW," or on the long-wave position, "LW," depending upon whether the signal is at the short-wave or long-wave end of the scale of wave lengths for the given set. Set the switch "M_4" on the "Min," position. This adjusts the coupling between the primary and secondary circuit to the best average value for the reception of undamped signals. Vary the primary receiving condenser, "C_6," slowly over its scale until the signals are heard. As the tuning with undamped signals is much sharper than with damped signals, the tuning must be accurately done in order to pick up signals—in many cases a change of 1 or 2 degrees on a condenser scale will completely cut out the signals. After the signals are picked up, adjust the primary and secondary condensers, "C_6" and "C_7," until the loudest signals are heard at the best note for the operator. If necessary, increase the amplification by moving the switch "R_4" toward the "Max." end of the scale.

If spark signals or damped wave signals are to be received, set the switch "S_1" at the "Spark" position and the switch "M_4" on the

"Max." position (sometimes "Min." position is preferable). If the wave length is known, set the secondary receiving condenser, "C_7," at the given wave length as shown on the table; set the switch "L_4" in the short or long wave position, depending upon the wave length to be received; and vary the primary receiving condenser, "C_6," until the signals are heard. Adjust both condensers and the amplification if necessary.

If the wave length of the undamped or damped wave signals is unknown, then they can be picked up only by trial, somewhat as follows: First, set the switch "L_4" at, say, the long-wave position; the primary condenser, "C_6," near the 100-degree end of its scale; and vary the secondary condenser, "C_7," slowly over its scale, until the signals are picked up. If no signals are heard, set the primary condenser near 80 degrees on its scale and vary the secondary condenser as before. Proceed in this way by repeated trials until the signals are found.

11. **How to transmit.**—Close the switch on the dynamotor panel.. Set the switch "S_2" in the "Trans." position. The filaments of the two VT-2 tubes should light and the dynamotor start. If only one filament lights it is certain that either there is a bad contact in the socket of the other or that its filament is burnt out. Under these conditions the set is operative, but it is working only at half power and consequently its range of operation and signal strength will be reduced. Close the sending key, which should immediately set the antenna circuit into oscillation and give a reading on the antenna ammeter "A." The wave length of the transmitter is determined by the constants of the antenna and can be adjusted to any given values within its range by means of the variable inductance "L_3" and variable condenser "C_5." In order to measure the wave length in use, the wavemeter must be used as follows: Set the button switch on contact "C" and with a screw driver adjust the screw at the "Lamp resistance" until the indicator lamp shows a dull red glow. Close the telegraph key and bring the meter near the lower left corner of the panel of the operating chest (set box) with the back of the wavemeter box parallel with the panel, thereby coupling the wavemeter coil with the variable inductance "L_3" in the antenna circuit. Vary the wavemeter handle slowly over its scale until the lamp shows its brightest glow. The wave length in meters can then be read directly from the wavemeter scale. In order to radiate a predetermined wave length, set the wavemeter at that wave length, close the telegraph key, bring the wavemeter near the lower left corner of the panel as before, and vary switch "L_3" of the transmitting set until contact is made which gives the brightest glow in the lamp. Then adjust condenser "C_5" until a still brighter glow is attained, and clamp in this position. The inductance adjustment is

in large steps and the condenser gives a continuous, fine adjustment for exact tuning of wave length to that of the wavemeter. The radiated wave length is then the same as that of the wavemeter setting and the set is ready for transmitting. Set the button switch of the wavemeter back on contact "A" so as to cut the battery out of circuit.

Under some conditions the antenna ammeter may not show a reading when the key is pressed. This generally indicates that the filaments of the VT–2 tubes are not hot enough and that there are no oscillations being developed. The current through them should be slightly increased by turning the switch "R_1" from the minimum position toward the maximum position until the ammeter indicates that there are oscillations, and that these are always developed with the closing of the key.

Under average field conditions the SCR–79–A set should give an antenna current of about 0.4 of an ampere and the SCR–99 set more than 0.5.

Section IV.

CARE OF SETS.

12. Handling and storage.—A careful handling is due any radio set, as the apparatus is very compact and there are a large number of connections inside the operating chest (set box). Careless, rough handling may dislodge the apparatus and will surely weaken or entirely break some connections. The set should not be permitted to become wet if it is possible to prevent it. If, for any reason, the set does become wet, either from exposure to rain or a long spell of damp weather, it should be carefully dried out but not exposed to any direct heat, as from a stove or radiator. The sets should be stored in a dry place that is free from dust.

13. The telephones.—The telephone receivers, Type P–11, must be carefully handled, special care being taken not to injure the diaphragm. If the diaphragm is bent or dented it may touch the pole pieces of the magnet and the magnetic attraction may be so strong that it will be held there with the result that the telephone becomes "dead." In order to obtain the correct clearance between the diaphragm and the poles it has been found necessary to grind the latter *after the assembly* of the telephone, as otherwise the standard parts can not be assembled with sufficient accuracy. For this reason the telephones should never be taken apart, as it is certain that the adjustments will be disturbed. If it becomes necessary to replace the cords the connections to the plug and to the receivers should be made so that the steady current from the plate battery will cause the mag-

netic flux in the receivers to be in the same direction as the flux of the permanent magnet; otherwise the magnet will be partially demagnetized and the efficiency of the telephones reduced. The following facts will enable one to make the correct connections: The spring of the telephone jack in the operating chest is positive with respect to its sleeve, and hence when the telephone is plugged in its tip will be positive and its sleeve negative. The telephone magnets are so wound that when the diaphragm is uppermost and the terminals are toward the operator, the right-hand terminal is positive. The cords have a colored thread or tracer running through them so as to give a color scheme to identify the various wires—as green, white, and red; the green tracer cord should always be connected to the tip. It then becomes the positive wire and should be connected to the right-hand terminal of one of the receivers; the white cord should be connected to the left terminal of the same receiver and to the right-hand terminal of the other receiver; and the red cord should be connected to the left terminal of this receiver and to the sleeve of the plug. In putting the telephones away into their compartment, the following standard practice should be followed in order to protect the diaphragm and the terminals: Place the two receivers with the faces of the caps parallel and together so that all access to the diaphragm is closed; and then bind them in this position by winding the telephone cord around the outside of the headband, beginning close to the cap.

14. Don'ts.—Don't fail to oil the dynamo after each two hours operation, with a few drops of oil.

Don't use too much oil on the dynamotor, as it will leak out on the commutator and cause sparking and other troubles.

Don't fail to keep the panel of the dynamotor clean, especially between the 300-volt leads.

Don't fail to have the control switch on the operating chest (set box) on the "Off" position before pulling the dynamotor switch.

Don't fail to see that the dynamotor switch is closed before placing the control switch on the operating chest (set box) in the "Transmit" position.

Don't use higher potentials than are supplied by the batteries furnished with the set.

Don't fail to check all the connections you have made before trying to operate the set, either for sending or receiving.

Don't fail to inspect connections of the high-volt battery occasionally and to renew it when they are defective.

Don't fail to store all spare parts so they can not shift in transportation.

SECTION V.

PRINCIPLES EMBODIED IN THE SETS.

15. Transmitter.—The transmitting circuit shown in simplified form in figure 5 is a modification of one of the fundamental oscillation circuits. The antenna circuit consisting of the antenna, the inductance L_3 shunted by small variable air condenser C_5, the condenser C_4, and the ground is the circuit which determines the frequency of oscillations of the set. In the valve circuits proper the inductance L_1 is the grid coil and serves as a reactance or feed-back coil, being coupled

TRANSMITTING CIRCUIT — SIMPLIFIED

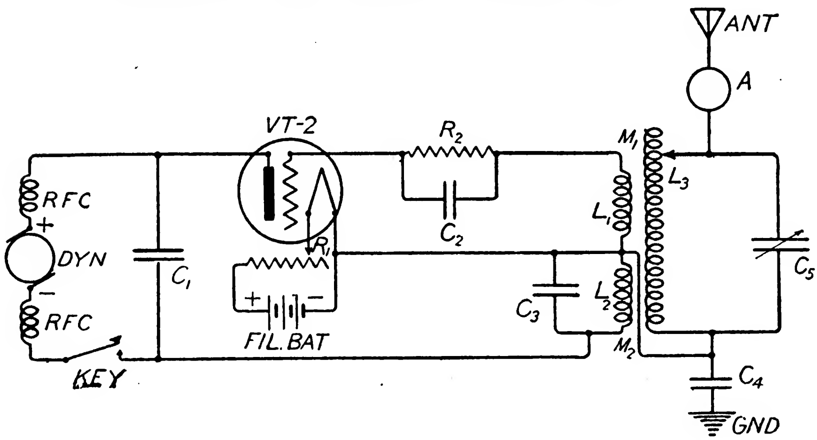

FIG. 5.

to the antenna coil L_3. The plate coil L_2 is the driving coil and is also coupled with the antenna coil L_3.

The high potential voltage, approximately 350 volts, is supplied by the dynamotor to the vacuum tubes. The key used in telegraphing is connected directly in series with the dynamotor. In order to protect the operator from possible shocks, the whole apparatus, including the generator side of the dynamotor, is carefully insulated from the ground. It is for this purpose that the large condenser C_4 is inserted in the antenna ground lead. The condenser C_3, which shunts the plate coil, has a capacity of 450 microfarads and aids in giving steady and uniform oscillations at all wave lengths. The design of the coils L_1, L_2, and L_3 and their relation to one another is such that the required changes in coupling are automatically secured in approximately proper proportions that correspond with the wave-

length changes produced by manipulation of the wave-length switch, which changes the number of turns in series in the inductance L_3. The design of these coils, together with the condenser C_3, makes a separate coupling adjustment unnecessary, thus simplifying the operation of the set. The resistance R_2 and its by-pass condenser C_2 in the grid circuit are of such value to insure a negative voltage on the grid during oscillations and at the same time to put upon the grid, when there are no oscillations taking place in the tube, a potential which will permit oscillations to be readily started. The small variable air condenser C_5 shunted across the antenna inductance L_3 permits more exact changes in the wave length of the antenna to be made than is secured by the taps on the antenna inductance. It also, together with the connection from the tube circuit to the antenna circuit, insures the starting of oscillations when the key is closed. It is to be noted that the connection between the tube circuits and antenna circuits gives a direct coupling in addition to the inductive coupling between them.

The detail of operation is as follows: With the key open there are no oscillations occurring in the set, the plate being at a high positive potential and the grid having a negative potential with respect to the filament, being connected with the negative side of the filament battery. Closing the key disturbs the conditions as set forth above, as it throws a negative potential on the filament and because of the resistance R_2 a still higher negative potential on the grid. There is therefore a surge of current in the plate circuit which passes through the plate coil L_2 and starts oscillations in the antenna circuit. The antenna circuit induces oscillations in the grid coil L_1, which affects the grid potential, and thus the oscillations are built up. The tube circuits are connected to the antenna circuit so that if a surge of current through L_2 should fail to start oscillations the sudden application of the high negative potential to the antenna circuit will upset its stabilized condition and start oscillations therein. This will cause the tube to oscillate as noted above.

The condenser C_1 furnishes a path for the oscillations so that they will not pass through the dynamotor. They are compelled to take this path because the dynamotor has in series with its leads radio frequency chokes which prevent the passage of high frequency oscillations. The radio frequency choke coils, RFC, together with the by-pass condenser C_1, serve also to smooth out the commutator ripples that may be present in the dynamotor. The radio frequency choke coils have an inductance each of 3 millihenries and a resistance of 6.9 ohms. The inductance reactance of each coil then at frequency of 158,000 (corresponding to 1,900 meters) is nearly 3,000 ohms. Their reactance to the commutator ripples which at the usual

speed would occur at about a rate of 1,785 per second is 34 ohms, approximately.[1]

16. Receiver.—The primary circuit of the receiver consists of the antenna, the inductance coil L_4 having two taps, a variable condenser C_6, together with a fixed condenser C_4 and the ground, all in series. The coupling between the primary circuit described above and the secondary circuit is variable in two steps marked "Minimum" and "Maximum," on the control handle. The "Min." gives a 2 per cent coupling while the "Max." gives a 6 per cent coupling. The secondary consists of an inductance L_6 shunted by a variable air condenser C_7, across which is placed the grid and filament of the detector tube. The two other VT–1 tubes are used as low-frequency amplifiers, they being connected by intervalve transformers. The simplified circuits are shown in figure 6. It is to be noted that the

RECEIVING CIRCUIT ~ SIMPLIFIED

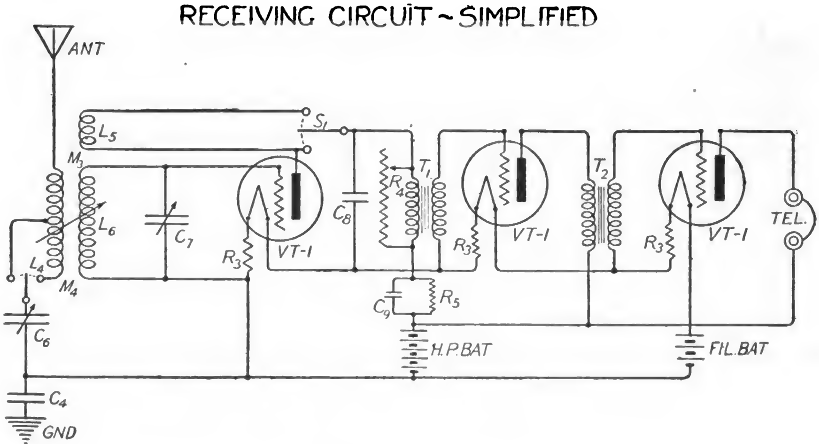

FIG. 6.

primary of the transformers between the detector and the first amplifying tube is shunted by a variable resistance. Variation of this resistance changes the amount of current passing through the primary of the transformer and hence is a control of the amount of amplification given by the set. This is found convenient especially in cutting down the amplification for the purpose of avoiding interference.

The detector vacuum tube operates on the bend of its characteristic curve, the resistance R_5, together with the resistance R_3, insuring the proper relative potentials of the filament, grid, and plate for it to act as a detector. The resistance R_5 is shunted by the by-pass

[1] The transmitting circuits employed in the SCR–79–A and 99 sets are fully discussed in treatises on vacuum tubes as applied to radio telegraphy. For a full mathematical discussion, see chapter 8, particularly section 89, of "Thermionic Vacuum Tube" by Van Der Bijl.

condenser C_9 to permit free passage of oscillations. A tickler coil L_5 permanently coupled with the secondary inductance L_6 causes the detector tube to oscillate when thrown in circuit, thus making the first tube an autodyne. These oscillations, whose frequency is determined by the characteristics of the secondary circuits, L_6 and C_7, produce with the incoming oscillations a beat note which is used in receiving undamped waves.

The purity of the autodyne note so produced depends upon the constancy of the frequency in both the receiver and transmitter. As the frequency depends in part upon the capacity in the circuit, it is evident that the capacity must be allowed to vary only as desired for tuning of the circuits and adjusting the pitch of the note in the receiver. If no precautions are taken, the approach of the operator's hand, or even its contact on the insulating handle of the receiving detector, may so change its capacity as to cause the autodyne note to become inaudible. This trouble has been avoided in these sets by connecting the moving plate of the transmitting wave-length adjustment, the receiving primary and receiving secondary condenser plates and their metal parts together, so as to form a shield. The approach of the operator's hand, therefore, does not have any appreciable effect on the autodyne note.

SECTION VI.

PARTS LIST OF SETS.

17. Equipments in 79–A set.—The SCR–79–A comprises the following equipment:

One equipment, Type PE–7.
One equipment, Type RE–5–A.
One equipment, Type A–9–A.

18. Equipments in 99 set.—The SCR–99 comprises the following equipment:

One equipment, Type PE–7.
One equipment, Type RE–7.
One equipment, Type A–9–A.

19. Parts comprising above equipments.—These equipments are made up of parts as noted below:

Equipment, Type PE–7:
Battery, Type BB–14 (9).
Box, type BC–25 or BC–25–A (1).
Dynamotor, Type DM–1 (1).

Equipment, Type A–9–A:
- Antenna, Type AN–8 (2).
- Bag, Type BG–12 (2).
- Cord, sash, No. 5, olive drab (300 feet).
- Guy, Type GY–4 (8).
- Hammer, 2-face, 2-pound (1).
- Insulator, Type IN–10 (4).
- Mast section, Type MS–14 (12) 9 in use; 3 spare.
- Mat, Type MT–5 (3).
- Pliers, combination, 6-inch (1 pair).
- Reel, Type RL–3 (8).
- Roll, Type M–15 (1).
- Stake, Type GP–8 (12).
- Tape, friction (1 roll).
- Wire, Type W–4 (50 feet).
- Wire, Type W–6 (300 feet).
- Wire, Type W–24 (750 feet).

Equipment, Type RE–5–A:
- Battery, Type BA–2 (4) 2 in use; 2 spare.
- Battery, Type BA–4 (4) 1 in use; 3 spare.
- Chest, Type BC–43 (1).
- Clock, Type I–15 (1).
- Cord, Type CD–15 (3).
- Cord, Type CD–38 (5).
- Cord, Type CD–47 (2).
- Cord, Type CD–48 (2).
- Cord, Type CD–49 (2).
- Head set, Type P–11 (2).
- Key, Type J–12 (1).
- Lamp, Type LM–4 (4) (for wavemeter), 1 in use; 3 spare.
- Pliers, combination, 6-inch (1 pair).
- Screw driver, 2½-inch blade (1).
- Set box (operating chest), Type BC–32–A (1).
- Set box (wavemeter), Type BC–40 (1).
- Tape, friction (½ pound).
- Tube, Type VT–1 (6) 3 in use; 3 spare.
- Tube, Type VT–2 (4) 2 in use; 2 spare.
- Voltmeter, Type I–10 (1).
- Wire, Type W–7 (2 pounds).
- Radio Communication Pamphlet No. 17 (1).

Equipment, Type RE–7:
- Battery, Type BA–2 (4) 2 in use; 2 spare.
- Battery, Type BA–4 (4) 1 in use; 3 spare.
- Chest, Type BC–43 (1).
- Clock, Type I–15 (1).

Equipment, Type RE–7—Continued.

Cord, Type CD–15 (3).
Cord, Type CD–38 (5).
Cord, Type CD–47 (2).
Cord, Type CD–48 (2).
Cord, Type CD–49 (2).
Head set, Type P–11 (2).
Key, Type J–12 (1).
Lamp, Type LM–4 (4) (for wavemeter), 1 in use; 3 spare.
Pliers, combination, 6-inch (1 pair).
Screw driver, 2½-inch blade (1).
Set box (operating chest), Type BC–45 (1).
Set box (wavemeter), Type BC–49 (1).
Tape, friction (½ pound).
Tube, Type VT–VT–1 (6) 3 in use; 3 spare.
Tube, Type VT–2 (4) 2 in use; 2 spare.
Voltmeter, Type I–10 (1).
Wire, Type W–7 (2 pounds).

SIGNAL CORPS PAMPHLETS.

(Corrected to November 1, 1921.)

RADIO COMMUNICATION PAMPHLETS.

(Formerly designated Radio Pamphlets.)

No.
1. Elementary Principles of Radio Telegraphy and Telephony (edition of 4–28–21) (W. D. D. No. 1064).
2. Antenna Systems.
3. Radio Receiving Sets (SCR–54 and SCR–54–A) and Vacuum Tube Detector Equipment (Type DT–3–A).
5. Airplane Radio Telegraph Transmitting Sets (Types SCR–65 and 65–A).
11. Radio Telegraph Transmitting Sets (SCR–74; SCR–74–A).
13. Airplane Radio Telegraph Transmitting Set (Type SCR–73).
14. Radio Telegraph Transmitting Set (Type SCR–69).
17. Sets, U. W. Radio Telegraph, Types SCR–79–A and SCR–99. (W. D. D. No. 1084.)
20. Airplane Radio Telephone Sets (Types SCR–68; SCR–68–A; SCR–114; SCR–116; SCR–59; SCR–59–A; SCR–75; SCR–115).
21. Theory and Use of Wavemeters (Types SCR–60; SCR–61).
22. Ground Radio Telephone Sets (Types SCR–67; SCR–67–A).
23. U. W. Airplane Radio Telegraph Set (Type SCR–80).
24. Tank Radio Telegraph Set (Type SCR–78–A).
25. Set, Radio Telegraph, Type SCR–105 (W. D. D. No. 1077).
26. Sets, U. W. Radio Telegraph, Types SCR–127 and SCR–130 (W. D. D. No. 1056).
30. The Radio Mechanic and the Airplane.
40. The Principles Underlying Radio Communication (edition of May, 1921) (W. D. D. No. 1069).

WIRE COMMUNICATION PAMPHLETS.

(Formerly designated Electrical Engineering Pamphlets.)

1. The Buzzerphone (Type EE–1).
2. Monocord Switchboards of Units Type EE–2 and Type EE–2–A and Monocord Switchboard Operator's Set, Type EE–64 (W. D. D. No. 1081).
3. Field Telephones (Types EE–3; EE–4; EE–5).
4. Laying Cable in the Forward Area (formerly designated Training Pamphlet No. 3).
6. Trench Line Construction (formerly designated Training Pamphlet No. 6–a).
7. Signal Corps Universal Test Set, Type EE–65 (W. D. D. No. 1020).
10. Wire Axis Installation and Maintenance Within the Division (W. D. D. No. 1068).

TRAINING PAMPHLETS.

1. Elementary Electricity (edition of 1–1–21) (W. D. D. No. 1055).
4. Visual Signaling.
5. The Homing Pigeon, Care and Training (W. D. D. No. 1000).
7. Primary Batteries (formerly designated Radio Pamphlet No. 7).
8. Storage Batteries (formerly designated Radio Pamphlet No. 8).

FIELD PAMPHLETS.

1. Directions for Using the 24-CM. Signal Lamp (Type EE–7).
2. Directions for Using the 14-CM. Signal Lamp (Type EE–6).
3. Directions for Using the Two-Way T. P. S. Set (Type SCR–76).

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GROUND RADIO TELEPHONE SETS

(Types SCR-67 and SCR-67-A)

RADIO COMMUNICATION PAMPHLET No. 22

PREPARED IN THE OFFICE OF
THE CHIEF SIGNAL OFFICER

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WAR DEPARTMENT,

WASHINGTON, *December 5, 1921.*

The following publication, entitled "Ground Radio Telephone Sets (Types SCR-67 and SCR-67-A)," Radio Communication Pamphlet No. 22, is published for the information and guidance of all concerned.

[062.1, A. G. O.]

BY ORDER OF THE SECRETARY OF WAR:

JOHN J. PERSHING,
General of the Armies,
Chief of Staff.

OFFICIAL:
P. C. HARRIS,
The Adjutant General.

GROUND RADIO TELEPHONE SETS.

(Types SCR-67 and SCR-67-A.)

The type SCR–67 set is a two-way radio telephone set for use on the ground in communicating with a similar set, or with the airplane radio telephone sets types SCR–59, SCR–68, and other or similar sets. The type SCR–67–A set is an improvement of the type SCR–67 set, and differs from the latter in minor details only, which do not affect the method of operation, or the explanation of the theory of the circuits. The circuits given here are those of the type SCR–67–A set, and the points in which the circuits of the type SCR–67 set differ are noted in the text and indicated in the drawings, the type SCR–67 constants and other variations being indicated in parentheses and dotted lines in figure 2, except for the wiring of the three-position power switch.

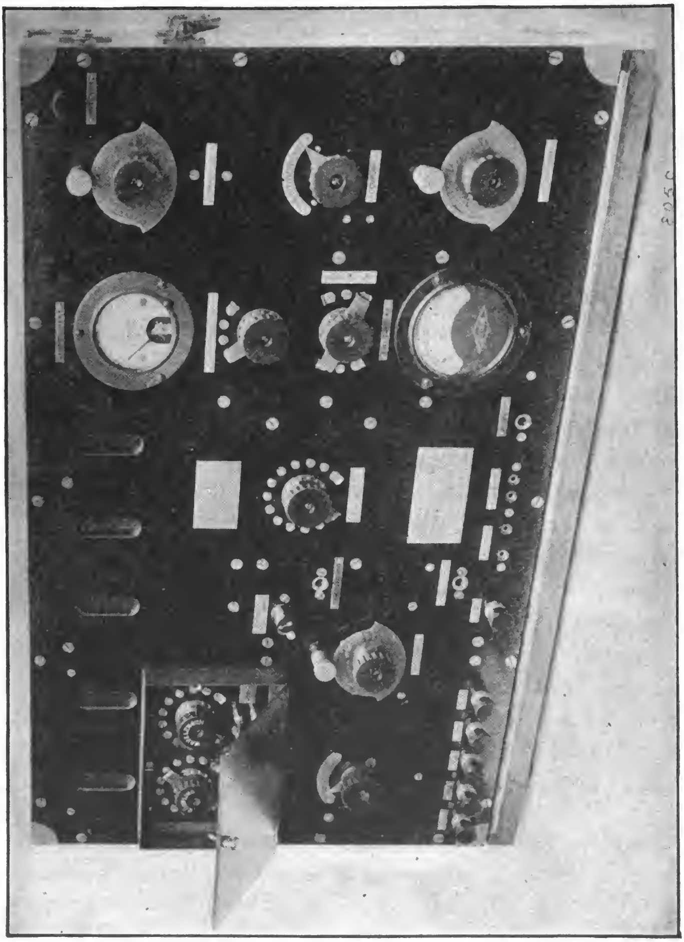
The average working range of either set when used with one of the airplane sets mentioned above, is 2 to 3 miles. This range depends to a considerable extent on the adjustments of the set, the type antenna used, and on the quality and distinctness of the operator's voice. When communicating with a ground set, the range may be as great as 5 to 7 miles.

The range of wave lengths is from 250 to 450 meters when transmitting, and from 200 to 700 or 800 meters when receiving and making use of a suitable antenna. Some antenna constructions are given in a later paragraph.

THEORY UNDERLYING THE OPERATION OF THE SET.

The complete theory of radio telephony is not taken up in this pamphlet. For this, reference is made to Radio Communication Pamphlets Nos. 1, 20, and 40. The principle of transmission involves the generation of undamped oscillations of a frequency greater than that of audible vibrations in the antenna circuit, and the varying of the amplitude of these oscillations proportionally to the voice modulations to be transmitted. These modulated high frequency oscillations, when rectified in the receiving circuit, produce in the telephone receivers a current of amplitude varying proportionally to the voice modulations at the transmitting station, and therefore reproduce the speech. The process will be better understood after the description of the circuits has been given.

A complete circuit diagram of the type SCR–67–A set is given in figure 1. By operating the three-position switch, marked on the panel "Off," "12–V on," "Power on," the set may be used either for receiving alone or for receiving and transmitting. For the latter position of the switch the transmitting circuit is connected by depressing a control push button, while the receiving circuit is con-



Operating panel on set box, Type BC–13 used in set, Type SCR–67.

nected when the push button is released. These two circuits are analyzed separately in the following paragraphs.

Theory of the transmitting circuit.—The circuit in use when transmitting is shown schematically in figure 2. The same letters and names are used as in figure 1, so that reference may be made to both diagrams if desired.

Undamped oscillations are generated by a type VT–2 three-electrode vacuum tube. The filament of this tube is heated by the current of a 12-volt storage battery. In series with the latter is a rheostat for regulating the current, and an ammeter. The negative side of the circuit is connected to ground.

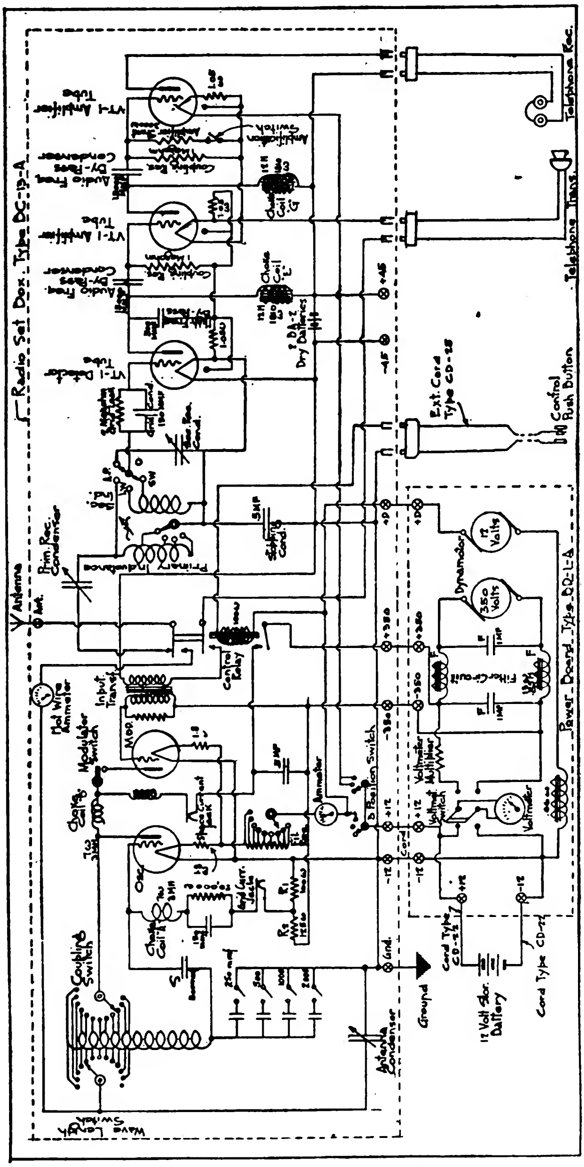


FIG. 1.—Complete schematic circuit diagram of the SCR–67–A.

A constant positive potential of about 350 volts is applied to the plate of the tube by means of a type DM–2 dynamotor, the low-voltage side of which is run by the same 12-volt battery that furnishes the

filament-heating current. In series with the plate circuit is a short-circuiting jack in which a plug connected to a milliammeter may be inserted to read the space current in the tube. The function of the choke coils marked " B " and " D," and that of resistances R_1, R_2, and R_3 will be explained later. A filter circuit, comprising two coils and two condensers F, is connected across the 350-volt terminals of the dynamotor for the purpose of minimizing the pulsations of current resulting from commutation.

A constant negative potential is impressed upon the grid of the oscillator tube, which is the voltage drop across a 100-ohm resistance connected between the filament and the grid. In series with this resistance is a 20,000-ohm resistance and a choke coil marked "A." The latter prevents any high frequency oscillations from flowing through this grid circuit. The 20,000-ohm resistance is shunted by a condenser, and it provides the proper negative potential when the tube is oscillating. A short-circuiting jack is also in series with the circuit. This permits the insertion of a plug for connecting in a milliammeter.

In the type SCR–67 set, resistance R_1 is 130 ohms instead of 100 ohms, and 10,000 ohms are used instead of 20,000 for the high resistance. The choke coil A and condenser C are also omitted.

The grid and plate circuits just described are coupled so that the tube will generate oscillations. The oscillatory circuit comprises a grid coupling condenser, the antenna, and the transmitting inductance coil. The grid coupling is effected through a fixed condenser S in series with any one or all of four fixed condensers in parallel, which may be connected as required by closing the small knife switches in the covered panel. This condenser S also serves as a stopping condenser in preventing the 350-volt direct current plate potential from being applied to the grid through the transmitting inductance. The plate coupling is made through the antenna and the transmitting inductance. The latter is connected at one end between the condenser S and the four parallel grid coupling condensers. At the other end of the coil are 12 taps, connected to two 12-point dial switches, marked " Coupling " and " Wave length," to which the plate and aerial are connected, respectively. The operation of the plate dial switch alters the plate coupling, while that of the aerial dial switch changes the transmitted wave length. A variable air condenser, marked "Antenna condenser " in figure 2, shunts the antenna and gives a continuous variation of wave length between any two consecutive taps of the wave length switch.

It may thus be seen from the above description how the direct current generated by the dynamotor is transformed by the oscillator tube into a high frequency undamped alternating current in the

antenna circuit, which continually radiates energy into space. The amplitude of these oscillations is proportional to the amount of current furnished by the dynamotor and flowing in the oscillator tube from the plate to the filament. A method of varying the amplitude of the oscillations is to vary the amount of direct current furnished to the tube. This is done in the type SCR–67 and SCR–67–A sets by means of a second three-electrode tube, called the modulator tube. The plate circuit of this tube shunts the plate circuit of the oscillator tube, as may best be seen from figure 2. The current generated in the 350-volt armature of the dynamotor will thus divide between

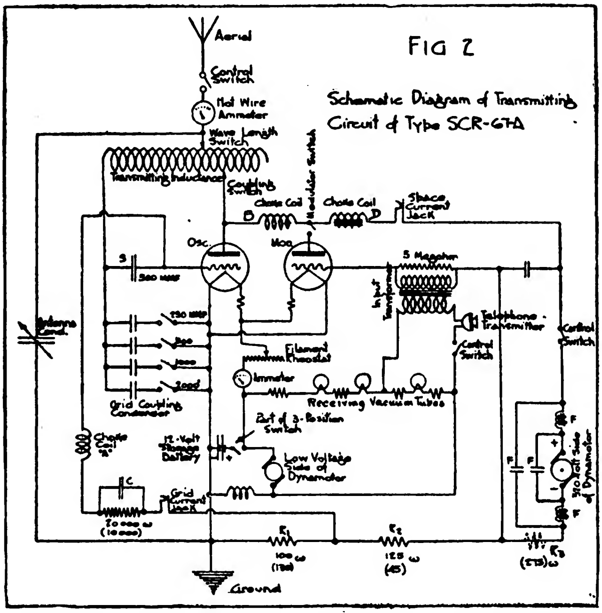


FIG. 2.—Schematic diagram of the transmitting circuit of the SCR–67–A.

the oscillator and the modulator tube in inverse proportion to their impedances.

In order to modulate the amplitude of the oscillations generated by the tube, the impedance of the modulator tube is varied by impressing upon the grid of this tube a potential the frequency and amplitude of which are determined by the strength and pitch of the voice. This is accomplished by connecting the secondary winding of a transformer, called the input transformer, between the grid and the negative side of the filament of the modulator tube. The grid circuit also comprises resistances R_1 and R_2, which give to the grid a negative potential derived from the drop across these two resistances due to the current flowing through them. This grid potential is of such value as to make the tube operate on the point of its characteristic curve which is most suitable for modulation.

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The primary circuit of the input transformer comprises a telephone transmitter. The current flowing in that circuit is obtained by connecting the circuit across the filament of one of the receiving tubes and two 1-ohm resistances. In case of the type SCR-67 set, the filament of the first amplifier tube is used, while for the type SCR-67-A set the detector tube is used instead.

The entire transmitting circuit having now been described, its theory of operation may be explained as follows:

The circuit will be ready for operation when the main switch, push button control switches, modulator switch, and the required grid coupling condenser switches are closed. The three-position switch will complete the filament heating circuit and the low voltage dynamotor circuit. The three control switches are closed by pressing the control push button.

By suitable adjustment of the wave length switch, plate coupling, grid coupling, and antenna condenser, the oscillator tube is made to generate undamped oscillations. This adjustment is made, in accordance with the rules given in a later paragraph, for the greatest antenna current with as small a plate and grid current as possible.

By closing the modulator switch, the plate circuit of the modulator tube is connected in parallel with that of the oscillator tube, so that the current from the dynamotor, instead of all flowing through the oscillator tube, will divide between the oscillator and modulator tubes. By talking into the telephone transmitter, an alternating emf. is induced in the secondary of the input transformer, and therefore on the grid of the modulator tube. This emf. is proportional to the voice modulations, and the impedance of the modulator tube is varied accordingly. The result is that a correspondingly greater or lesser part of the total constant current generated by the dynamotor will be shunted off the oscillator tube, by the modulator tube, and the amplitude of the oscillations is thus modulated. It is evident that the operation of this scheme will be satisfactory only if the current fed by the dynamotor is kept constant. This is insured by the presence of an iron core choke coil D in the plate circuit of the two tubes. A 0.5-megohm resistance is shunted around the input transformer secondary for improving its operation. The actual method of operating the transmitting circuit is explained under a separate heading.

Theory of the receiving circuit.—The circuits in use when receiving are shown schematically in figure 3. Reference may also be made to figure 1, where the same letters and designations are used. The primary (antenna) circuit comprises the aerial, a variable air condenser, an inductance coil variable in four steps, a large stopping condenser, and the ground. The stopping condenser does not stop the incoming high frequency oscillations, but prevents a short cir-

cuit in the filament circuit of the tubes. Inductively coupled to this circuit is the secondary oscillatory circuit, comprising a variable air condenser and an inductance coil variable in two steps, the entire coil being used when receiving long waves, and only half the coil being used for short waves. The secondary circuit may be entirely disconnected when the dial switch is placed in the aperiodic position, "AP." In this case, the detector tube is directly connected to the antenna circuit. This position cuts out the secondary tuned circuit and is used when searching for signals of unknown wave length.

The detector tube is a type VT–1 three-electrode tube having its filament and grid connected across the receiving inductance. A grid condenser shunted by a 2-megohm leak resistance is connected in series with the grid. The filament of this tube is in series with the filaments of the amplifier tubes, and is heated by the current from

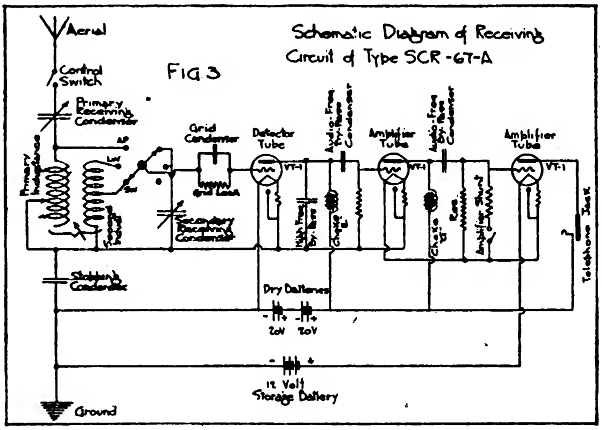


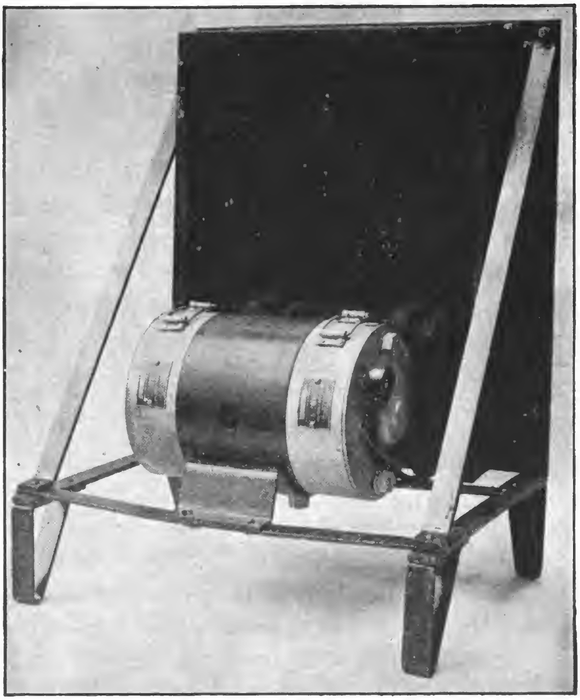
FIG. 3.—Schematic diagram of the receiving circuit of the SCR–67–A.

the 12-volt storage battery. The plate current of the detector tube is furnished by a 40-volt battery, made up of two type BA–2 dry batteries in series. In the case of the type SCR–67 set, one 20-volt BA–2 battery only is used for the detector tube. The high frequency currents are by-passed from the plate to the filament by a fixed condenser, while the audio frequency currents, in flowing through the choke coil E, induce in the latter a high alternating emf. This emf. is transferred through the grid stopping condenser to the grid of the first amplifier tube, correspondingly varying the plate current of that tube. The latter variations are therefore amplified repetitions of the detector tube plate current audio frequency variations. The charges induced on the grid of the first amplifier tube leak off to the filament through a 1-megohm resistance.

A similar scheme is used for coupling the first and second amplifier tubes. Both amplifiers work at a plate voltage of about 40 volts derived from the same battery that is used for the detector tube.

In the type SCR-67 set this plate potential is obtained by means of a second type BA-2 battery in series with the one used for the detector tube. Telephone receivers are plugged in the plate circuit of the last tube, and the degree of amplification may be reduced by closing the "Amplifier" switch, which connects a low resistance across the input circuit of the last amplifier tube, thus reducing the intensity of the sound in the telephones.

Summary of differences between the type SCR-67 and SCR-67-A sets.—The main differences between the type SCR-67 and SCR-67-A sets are the following: The choke coil A and condenser C, figure 2, do not exist in the type SCR-67 set. The grid resistance is 10,000



Rear of power board, showing dynamotor Type DM-2.

ohms in the type SCR-67 set and 20,000 ohms in the type SCR-67-A set. Resistances R_1 and R_2 are 130 and 45 ohms, respectively, in the SCR-67, and 100 and 125 ohms in SCR-67-A. Resistance R_3 exists in the type SCR-67 set only. The connections of the three-position switch are quite different. When in the middle position, all five tubes light with SCR-67, while the receiving tubes only are on in the SCR-67-A set. These differences may be noted in figures 5 and 6 at the end of the pamphlet.

COMPONENT PARTS OF THE SET.

The apparatus making up the set comprises the radio set box, type BC-13 or BC-13-A, which contains the radio circuits and

operating switches; the power board, in back of which is mounted the dynamotor and dynamotor filter circuit, and which also has a voltmeter for reading the storage battery voltage and the voltage generated by the dynamotor; the 12-volt storage battery; the telephone head set and transmitter; the control push button; and the connecting cords. The set box measures 23¾ by 15¼ by 6¼ inches over all. The power board measures 17⅝ by 13¼ by 10¼ inches. The various parts of the set are interconnected, as shown in the cording diagram, figure 4. Heavy wire should be used to connect the storage battery to the power board in order to reduce the resistance losses. This is an important point which affects the radiation to an appreciable extent.

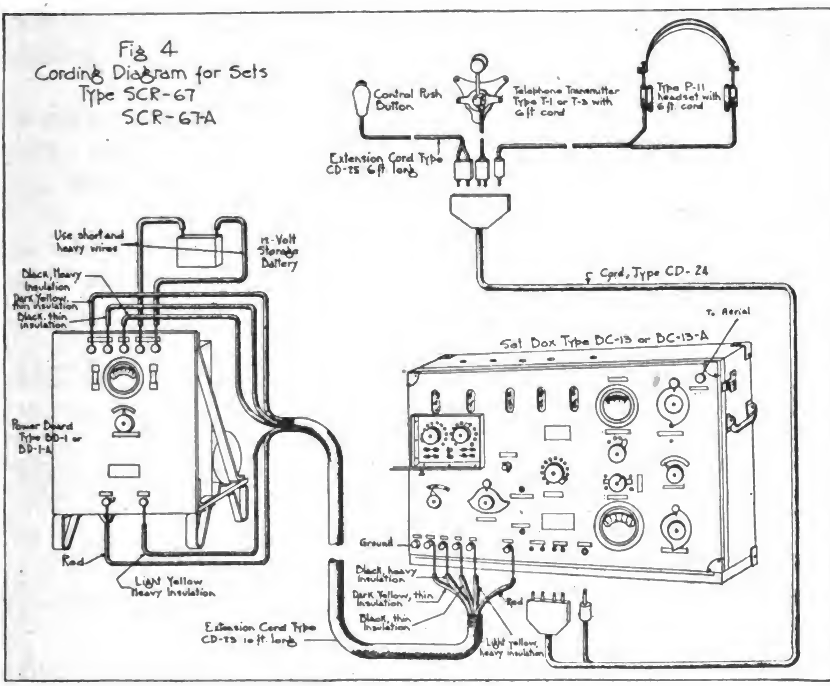


FIG. 4.—Cording diagram for sets, SCR–67 and SCR–67–A.

METHOD OF OPERATION.

Various types of antennae may be used with the ground telephone sets. Two factors which are of great importance in setting up the antenna are its resistance and natural wave length. The resistance should be as low as possible, preferably less than 20 ohms. The natural wave length must be shorter than the shortest wave length to be used for transmitting. The following types of antenna construction are suggested:

(*a*) An umbrella type antenna, 40 feet high, with six 50-foot aerial wires and six 90-foot insulated counterpoise wires. The

82083°—22——3

aerials are held in proper position by means of guy ropes 75 feet long. The natural wave length is 250 meters.

(*b*) A "V" antenna, 24 feet high, 100 feet long on each side, using two 100-foot insulated counterpoise wires or two buried ground mats. The natural wave length is about 250 meters.

(*c*) An inverted "L" antenna, 20 feet high, 100 feet long, with an insulated counterpoise wire 100 feet long. This has a natural wave length of 200 meters.

(*d*) An inverted "L" antenna, 20 feet high, 150 feet long, with an insulated counterpoise wire 150 feet long. This antenna has a natural wave length of 325 meters, and is recommended for use when working at wave lengths greater than this value.

Transmitting.—The set having been fully connected up as per cording diagram, figure 4, and using a suitable antenna, the method of operation is as follows:

It is well to calibrate the set in advance for a number of wave lengths, with the set connected to the antenna to be used. The method of calibrating the transmitting circuit, or of operating the latter when not previously calibrated, is given below.

1. Open the radio set box, and see that two type VT–2 tubes and three type VT–1 tubes are inserted in their proper sockets. The VT–2 tubes are at the left, the VT–1 tubes at the right of the box, as one faces the operating panel.

2. By means of a voltmeter, check the voltage and polarity of the dry batteries. The voltmeter should read not less than 36 volts, and should in general read 40 to 45 volts.

3. Close the set box and throw the voltmeter switch on the power board to "12" volts and check the storage battery voltage. This should be at least 12 volts, and may be 14 volts without damage to the apparatus. A voltage of 13 or 14 volts will, in fact, improve the operation of the set, but the latter limit should never be exceeded. After checking the voltage, throw the switch to "Off."

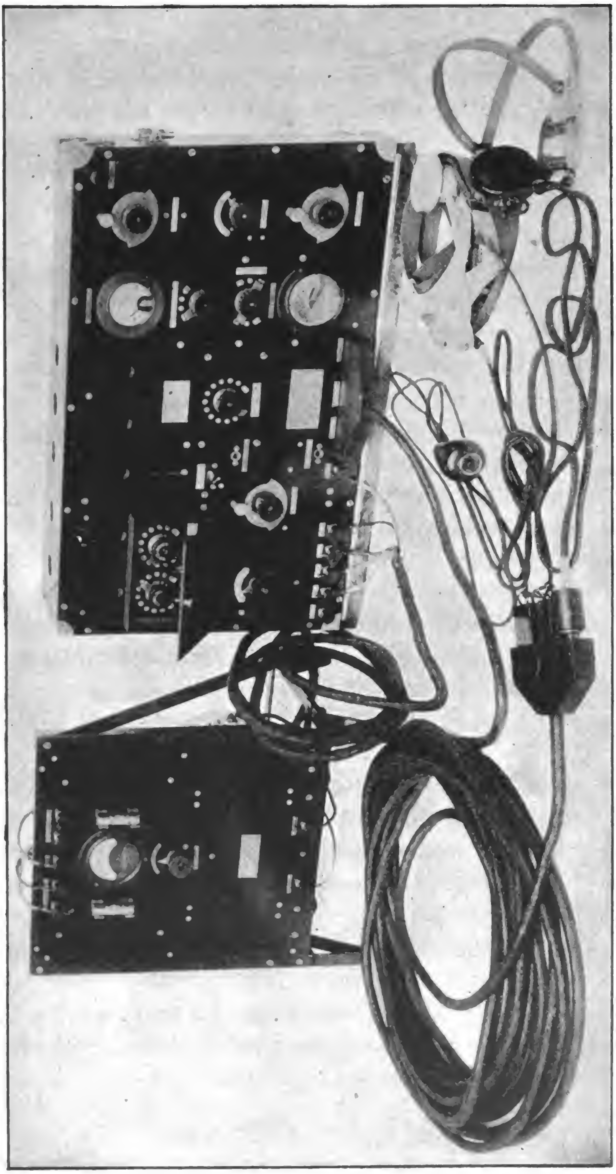
4. Place a type SCR–60–C or SCR–61 wavemeter near the left hand end of the radio set box and set it to the desired wave length. If the type SCR–61 wavemeter is used, insert type P–11 telephone receivers in the wavemeter jack, start the buzzer and adjust the crystal detector. Keep the buzzer running while adjusting the radio set. If the type SCR–60–C wavemeter is used, operate similarly, or better, simply read the galvanometer, without using the buzzer or telephone receivers.

5. Turn the filament current switch of the radio set box all the way to the left, to the position "Minimum."

6. Insert the milliammeter plugs in the jacks marked "Grid current" and "Space current." Two type I–7 ammeters may be used, with an extension cord type CD–57.

7. Open the modulator switch. This is the small vertical knife switch in the center of the covered panel.

8. Throw the three-position power switch all the way to the right, in the position marked "Power on." This should light the fila-



Set box and power board, showing extension cords used when it is desired to remove the dynamotor from close proximity to the set box to reduce the noise.

ments of all five vacuum tubes, should give a reading on the filament current ammeter, and should start the dynamotor.

9. Adjust the filament current so that the filament current ammeter will indicate 2.6 to 2.7 amp.

10. Press the control push button. This will connect the control relay, figure 1, across the 12-volt storage battery, which in turn will close the three contacts, corresponding to the control switches of figure 2. The plate current should be about 50 milliamp. if the oscillator tube is working properly.

11. Connect the 750 or the 1,000 micro-mfd. grid coupling condenser, by closing the corresponding knife switch in the covered panel, and set the 12-point "Coupling" dial switch so that the tube will oscillate, as indicated by a reading on the antenna ammeter.

12. Adjust then, in rotation and in the order mentioned, the "Wave length" switch, antenna transmitting condenser ("Cond. trans."), and "Coupling" switch until maximum response is obtained on the wavemeter. Also try various combinations of the four grid condenser switches, so that the grid current will be between 2 and 7 milliamp. The greater the wave length, the greater the grid condenser to be used.

13. Readjust the wave length switch and antenna condenser to perfect the tuning.

14. Readjust several times, in the order mentioned, the plate "Coupling" dial switch, grid coupling knife switches, and antenna transmitting condenser to secure that adjustment which will give, at the desired wave length, greatest radiation and smallest grid and plate current possible.

15. If the grid current is too high, increase the grid condenser. If the plate current is too high, increase the plate coupling. With a suitable antenna, the radiation should be from 0.3 to 0.6 amp.

16. Close the modulator switch in the covered panel. The plate current will be 60 to 70 milliamp. In no case should it exceed 80 milliamp.

17. The set is now ready for transmitting. Remove the wavemeter and the grid and plate milliammeters. When talking, speak in an even tone of voice, not too high nor loud, and with the lips close to the transmitter. It is essential that the push button be kept closed while transmitting.

18. An idea of the settings of the various switches may be obtained from the calibration chart given below. This chart was obtained with a type SCR-67 set, using an inverted "L" antenna having a natural wave length of about 200 meters. Such an antenna is not very well suited for use with this set.

Wave length.	Antenna switch point.	Coupling switch point.	Antenna transmitting condenser.	Grid coupling condenser.
235	1	12	100	500
250	2	12	100	750
300	5	12	70	1000
350	8	11	80	1000
400	11	11	26	1000
450	12	10	100	1000

CAUTION.—Do not touch the modulator and grid condenser switches with bare hands while the power is on.

Receiving.—The receiving circuit may be calibrated, after the set has been connected to the antenna, by means of a wavemeter which is set to a number of wave lengths, the set being tuned in as explained below, and the settings of the various switches recorded. If not calibrated in advance, or if the wave length to be received is unknown, the procedure is as follows:

1. Follow the instructions given in paragraphs 1, 2, 3, and 5 of the previous section.

2. Close the three-position power switch of the radio set box in the middle position, marked "12 volts." This should light the filaments of the three receiving tubes. The circuits in use are shown in figure 3. The antenna control switch, figure 2, is closed and it is not necessary to close the push button. If it is desired to transmit and receive, set the three-position switch to "Power on." When transmitting, press the push button; when receiving, release the push button. In case of the type SCR–67 set, all five vacuum tubes will light simultaneously when the power switch is in the "12-volt" or "Power on" position.

3. Set the three-point dial switch located above the filament current ammeter in the position "AP."

4. Adjust the receiving "Primary inductance" and the "Primary receiving condenser" until the signals are heard loudest.

5. Set the three-point dial switch to "LW" or "SW," and adjust the secondary receiving condenser for loudest signals, using maximum coupling if required.

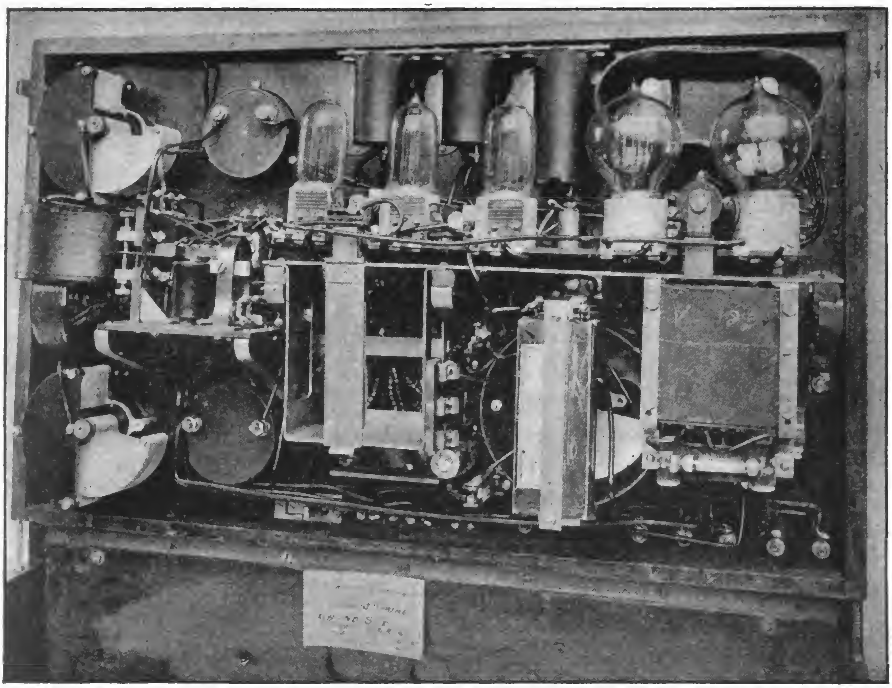
6. If the signals are too loud, set the "Amplifier" key to "Minimum." If they are not loud enough, set it to "Maximum." Also, reduce the coupling for protection against interference.

POSSIBLE SOURCES OF TROUBLE.

Frequently, the set does not operate satisfactorily on account of incomplete adjustment of the transmitting circuit. In making adjustments, each setting affects all the others, and it is therefore

necessary to go over all adjustments in the same order until proper conditions are obtained. Once the set is adjusted, it will therefore save time to record the settings and corresponding wave length. These settings will of course change if the antenna is changed.

With a set properly adjusted, the results are still dependent on the voice of the operator. The speech should be clear, rather slow and in an even, moderate tone, and with the lips close to the telephone transmitter.



Mounting of apparatus on the back of panel on set box, Type BC–13.

In general, it may be said that the set is operating properly when, with the switch on "Power on" and the control push button closed, and the amplification switch on "Minimum," the operator hears himself distinctly in the telephone receiver while talking in the transmitter in a low tone of voice. The explanation of this test is that the modulated oscillations of the transmitting circuit induce currents in the receiving inductance. The test is therefore a check on the working condition of the circuits, but may not be considered as a conclusive proof that the circuits are perfectly adjusted.

Some of the troubles which may be encountered in operating the set are mentioned below. The wiring diagrams of figures 5 and 6 may be helpful when tracing the circuits in the set box.

NOISE IN RECEIVER.

(*a*) Worn-out dry batteries. Voltage should not be less than 17.5 volts per battery.

(*b*) Noisy leak resistances.

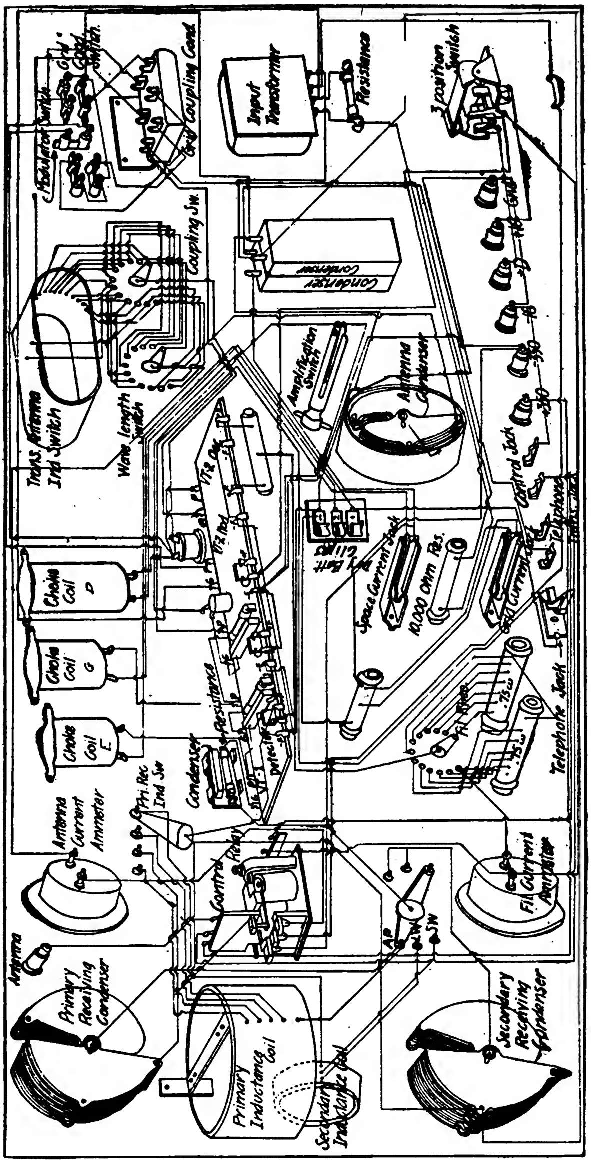


FIG. 5.—Actual wiring connections within the set box Type BC-13.

(*c*) Loose connections in plate, filament, or grid circuits. Inspect soldered connections, especially of long wires which may vibrate loose. Inspect connection clips of grid leak and telephone jack.

(*d*) Poor contact between vacuum tube and spring contacts in socket.

(*e*) Broken-down grid leak condenser. Remove condenser and test for click, using telephones.

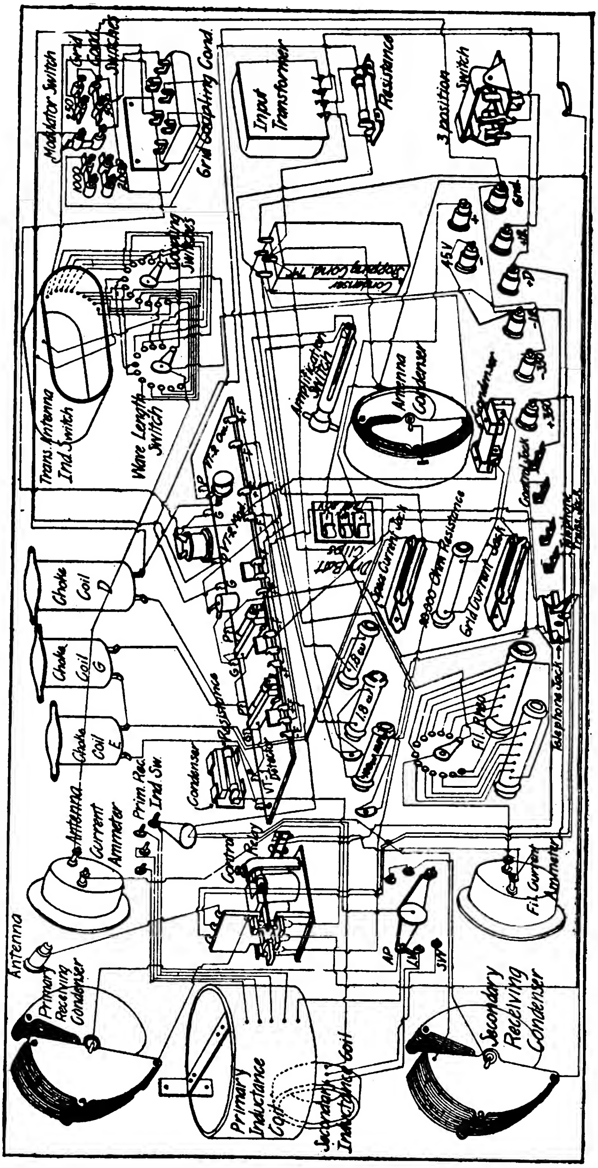


FIG. 6.—Actual wiring connections within the set box Type BC-13-A.

(*f*) Noisy detector vacuum tube.

(*g*) Sparking at dynamotor commutator, due to poor brushes or dirty commutator.

FAILURE TO RECEIVE.

(*a*) Tap on the detector tube. If a loud ringing noise is heard, the trouble is probably in the antenna primary and secondary circuits. If no noise is heard, the trouble is probably between the detector and telephones.

(*b*) Failure of filaments to light; due to broken filament in one of the receiver tubes (VT–1) or open in filament circuit. May also be due to broken-down antenna stopping condenser.

(*c*) Blocking of detector tube; due to too high resistance grid leak or open in grid circuit. Examine grid leak connecting clips.

(*d*) Receiving condenser short circuited, due to buckled plates; or antenna stopping condenser broken down.

FAILURE OF AMPLIFIER.

(*a*) Amplifier resistances may be burned out, or short-circuited, or the connections may be broken.

(*b*) Condenser terminals grounded to metal frame.

(*c*) Loose connections. Condenser terminal connections broken off.

FAILURE TO OSCILLATE.

(*a*) Failure to have any plate current with modulator switch open may be due to a failure to impress the plate voltage on the tube. Test direct current plate circuit for an open by shunting the plate and filament terminals of the tube socket with a buzzer or receiver. Test dynamotor voltage on power board. The milliammeter circuit may be open. Inspect plate current jack and plug. The contacts on the control relay may not operate properly. Too small a plate current may be due to too small a filament current.

(*b*) Failure to have any grid current may be due to a burned-out grid resistance. Test the latter by clicking through with the telephones. It may also be due to a burn-out or open in the R_2 and R_3 resistance (fig. 2), to an imperfect grid current jack, or burned-out ammeter.

(*c*) Oscillator tube filament may not light due to an open in the filament circuit.

(*d*) No reading on antenna ammeter may be due to an open in the antenna circuit. Ammeter may be burned out, or antenna inductance coil may be open. Test by buzzer. Antenna condenser may be shorted. Antenna switches may be faulty.

(*e*) Test grid coupling condenser by buzzer.

(*f*) Circuit may not be adjusted properly.

(*g*) Antenna insulator may leak, or antenna may be grounded.

OVERHEATING OF OSCILLATOR TUBE.

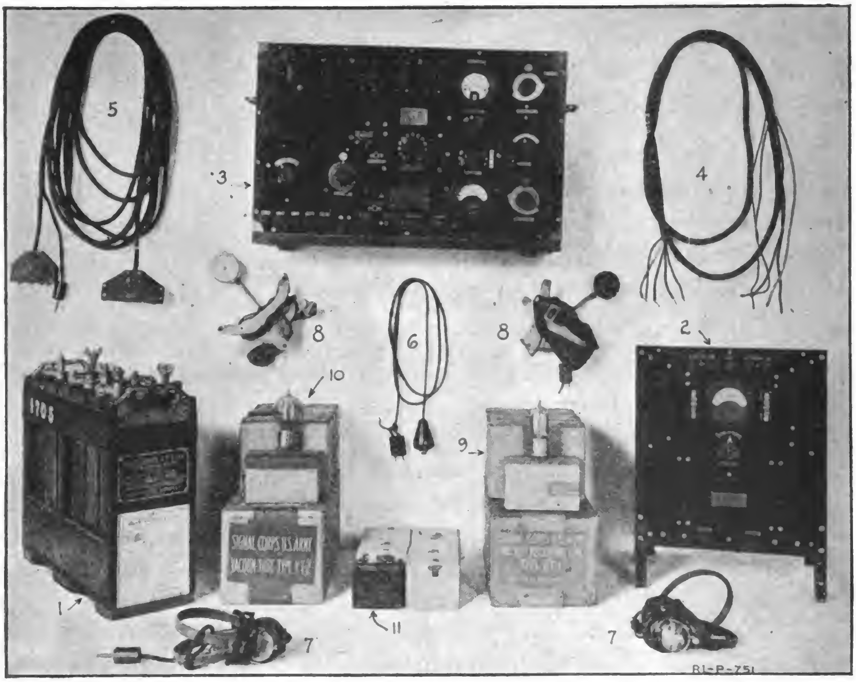
(*a*) Too much plate voltage.

(*b*) Improper adjustment of circuit.

(*c*) Lack of grid current or excessive grid current due to improper adjustment of circuit.
(*d*) Faulty tube.

FAILURE TO MODULATE.

(*a*) Receiving tube filaments may not light.
(*b*) Control relay contacts may not work.
(*c*) Open in modulator plate circuit. Modulator knife switch should be closed. If the latter is open, plate current ammeter should read 40 to 50 milliamp. When closed, space current should be 60 to 70 milliamp.



Component parts of the set.

(*d*) Iron core choke coil may be short-circuited.
(*e*) Faulty or burned out input transformer.
(*f*) Short circuit on input transformer secondary.
(*g*) Open circuit between transformer and grid of modulator tube.
(*h*) Faulty telephone transmitter.
(*i*) Faulty tube.
(*j*) Blocking of modulator may be due to too high or too low a plate current, or to improper resistances in plate circuit. A tendency of the tube to block will be evidenced by a high and unsteady reading on the plate current ammeter when blowing or whistling on the tele-

phone transmitter. Blocking of the modulator is also evidenced by the fact that when the operator talks into the transmitter while sending, he hears his speech interruptedly. A remedy, if the tube is not faulty, is to interchange the oscillator and modulator tubes.

PARTS LIST.

In ordering this set or parts of this set specification must be made by names and type numbers as listed below exactly. The designation printed in bold face type *only* will be used in requisitioning, making property returns, etc.

In ordering complete sets it is not necessary to itemize the parts; simply specify "Set, Radio Telephone, Type SCR-67." If all the parts listed under a group heading are desired, it is not necessary to itemize the parts; simply specify, for example, "1 Equipment Type PE-2."

The set is not complete unless it includes all of the items listed in the component parts table below:

SET, RADIO TELEPHONE, TYPE SCR-67.

1 **Equipment Type PE-2**; power.
- 4 **Batteries Type BB-5**; 2 in use, 2 spare.
- 1 **Powerboard Type BD-1.**
- 1 **Cord Type CD-22.**

1 **Equipment Type RE-2**; radio.
- 1 **Set Box Type BC-13.**
- 1 **Cord Type CD-23**; powerboard to set box.
- 1 **Cord Type CD-24.**
- 1 **Cord Type CD-25.**
- 2 **Head Sets Type P-11**; 1 in use, 1 spare.
- 1 **Radio Communication Pamphlet No. 22.**
- 2 **Transmitters Type T-1**; 1 in use, 1 spare.
- 16 **Tubes Type VT-1**; 3 in use, 13 spare.
- 16 **Tubes Type VT-2**; 2 in use, 14 spare.
- 8 **Batteries Type BA-2**; 2 in use, 6 spare.

1 **Equipment Type A-9**; antenna.
- 6 **Insulators Type IN-5.**
- 6 **Insulators Type IN-7.**
- 6 **Couplers Type FT-2.**
- 3 **Mats Type MT-3.**
- 750 ft. **Wire Type W-1.**
- 2 **Reels Type RL-3.**
- 300 ft. **Wire Type W-6.**

6 Mast Sections Type MS–5.
2 Bags Type BG–14.
12 Stakes Type GP–3.
1 Bag Type BG–8.
50 ft. Wire Type W–4.
1 Hammer Type HM–1.
½ lb. Marlin Type RP–2.
300 ft. Cord Type RP–3.

SET, RADIO TELEPHONE, TYPE SCR–67–A.

1 Equipment Type PE–2–A; power	*
6 Batteries Type BB–5 or Type BB–14	(1)
1 Powerboard Type BD–1–A	(2)
1 Cord Type CD–48.	
2 Cords Type CD–38; 1 in use, 1 spare.	
1 Equipment Type RE–2–A; radio.	
1 Set Box Type BC–13–A	(3)
1 Cord Type CD–23; powerboard to set box	(4)
1 Cord Type CD–25; set box to operator's cut-in switch	(5)
1 Cord Type CD–24; set box to operator's jack	(6)
2 Head Sets Type P–11; 1 in use, 1 spare	(7)
1 Radio Communication Pamphlet No. 22.	
2 Transmitters Type T–3; 1 in use, 1 spare	(8)
16 Tubes Type VT–1; 3 in use, 13 spare	(9)
16 Tubes Type VT–2; 2 in use, 14 spare	(10)
8 Batteries Type BA–2; 2 in use, 6 spare	(11)

1 Equipment Type A–9; antenna.
6 Insulators Type IN–5.
6 Insulators Type IN–7.
6 Couplers Type FT–2.
3 Mats Type MT–3.
750 ft. Wire Type W–1.
2 Reels Type RL–3.
300 ft. Wire Type W–6.
6 Mast Sections Type MS–5.
2 Bags Type BG–14.
12 Stakes Type GP–3.
1 Bag Type BG–8.
50 ft. Wire Type W–4.
1 Hammer Type HM–1.
½ lb. Marlin Type RP–2.
300 ft. Cord Type RP–3.

*Numbers in parentheses at the right refer to the corresponding part in the illustration on page 18.

SIGNAL CORPS PAMPHLETS.

(Corrected to February 1, 1922.)

RADIO COMMUNICATION PAMPHLETS.

(Formerly designated Radio Pamphlets.)

No.

1. Elementary Principles of Radio Telegraphy and Telephony (edition of 4-28-21). (W. D. D. No. 1064).
2. Antenna Systems.
3. Radio Receiving Sets (SCR-54 and SCR-54-A) and Vacuum Tube Detector Equipment (Type DT-3-A).
5. Airplane Radio Telegraph Transmitting Sets (Types SCR-65 and 65-A).
9. Amplifiers and Heterodynes. (W. D. D. 1092.)
11. Radio Telegraph Transmitting Sets (SCR-74; SCR-74-A).
13. Airplane Radio Telegraph Transmitting Set (Type SCR-73).
14. Radio Telegraph Transmitting Set (Type SCR-69).
17. Sets, U. W. Radio Telegraph (Types SCR-79-A and SCR-99). (W. D. D. 1084.)
20. Airplane Radio Telephone Sets (Types SCR-68; SCR-68-A; SCR-114; SCR-116; SCR-59; SCR-59-A; SCR-75; SCR-115).
22. Ground Radio Telephone Sets (Types SCR-67; SCR-67-A). (W. D. D. 1091.)
23. U. W. Airplane Radio Telegraph Set (Type SCR-80).
24. Tank Radio Telegraph Set (Type SCR-78-A).
25. Set, Radio Telegraph, Type SCR-105. (W. D. D. 1077.)
26. Sets, U. W. Radio Telegraph, Types SCR-127 and SCR-130. (W. D. D. 1056.)
28. Wavemeters and Decremeters. (W. D. D. 1094.)
30. The Radio Mechanic and the Airplane.
40. The Principles Underlying Radio Communication (edition of May, 1921). (W. D. D. 1069.)

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2. Monocord Switchboards of Units Type EE-2 and Type EE-2-A and Monocord Switchboard Operator's Set Type EE-64. (W. D. D. 1081.)
3. Field Telephones (Types EE-3; EE-4; EE-5).
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6. Trench Line Construction (formerly designated Training Pamphlet No. 6-a).
7. Signal Corps Universal Test Set, Type EE-65. (W. D. D. 1020.) (2d edition.)
10. Wire Axis Installation and Maintenance Within the Division. (W. D. D. 1068.)

TRAINING PAMPHLETS.

1. Elementary Electricity (edition of 1-1-21). (W. D. D. 1055.)
4. Visual Signaling.
7. Primary Batteries (formerly designated Radio Pamphlet No. 7).
8. Storage Batteries (formerly designated Radio Pamphlet No. 8).

FIELD PAMPHLETS.

1. Directions for Using the 24-CM. Signal Lamp (Type EE-7).
2. Directions for Using the 14-CM. Signal Lamp (Type EE-6).

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W. D. D. No. 1077

W. D. D. No. 1077

SET, RADIO TELEGRAPH

TYPE SCR-105

Radio Communication Pamphlet No. 25

PREPARED IN THE OFFICE OF THE
CHIEF SIGNAL OFFICER

September, 1921

WASHINGTON
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1921

WAR DEPARTMENT

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WAR DEPARTMENT,
WASHINGTON, *September 17, 1921.*

The following publication, entitled "Set, Radio Telegraph, Type SCR–105," Radio Communication Pamphlet No. 25, is published for the information and guidance of all concerned.

[062.1, A. G. O.]

BY ORDER OF THE SECRETARY OF WAR:

JOHN J. PERSHING,
General of the Armies,
Chief of Staff.

OFFICIAL:
P. C. HARRIS,
The Adjutant General.

TABLE OF CONTENTS.

SET, RADIO TELEGRAPH, TYPE SCR-105.

GENERAL DESCRIPTION OF SET.

1. The SCR-105 is a transmitting and receiving quenched-spark radio set. It is designed to be used for communication between headquarters which are usually not more than 5 miles apart. It can maintain communication with a like set over a distance of 5 miles. If an amplifier is furnished with the receiving set, this distance is increased to 13 miles. The transmitting wave lengths are fixed at 150, 180, 210, 240, 270, and 300 meters. It can be tuned for the reception of damped waves and audio frequency modulated continuous waves at any wave length between 100 and 550 meters. The set is intended only for intermittent duty and should not be used for continuous sending. The equipment is so packed that the set may be carried by hand when necessary. There are three distinct equipments comprising the set; the power, the antenna, and the operating chest.

DESCRIPTION OF POWER EQUIPMENT.

2. Storage batteries Type BB-23 furnish the power. This battery is a 10-volt lead storage battery of a nonspill type of 20 ampere-hour capacity. There are five cells in individual celluloid jars, all being contained in a wood case with peepholes for showing when the battery acid is at the correct height. The battery complete weighs 26 pounds and is provided with a carrying strap. Its dimensions are 12¼ by 5 by 10 inches high. The three batteries are assigned as follows: One in use with the set; one spare, fully charged, with the set; and one at the charging point. (At the present time, however, only two batteries are being issued; one for use with the set and the other on charge.) A card containing the manufacturer's instructions accompanies each battery. Signal Corps Training Pamphlet No. 8 describes the care and charging of batteries.

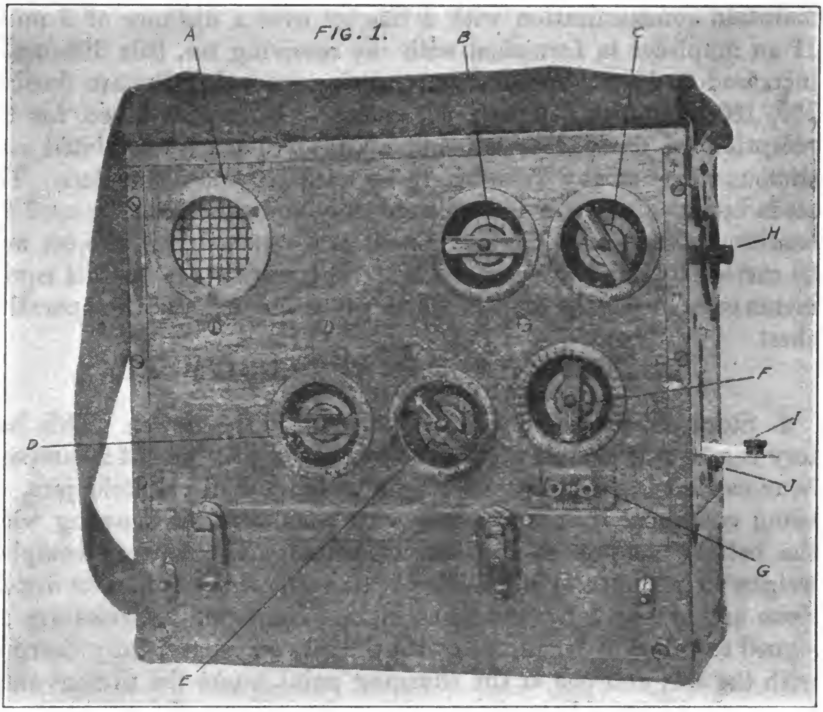
DESCRIPTION OF ANTENNA EQUIPMENT.

3. The antenna is a single wire inverted L 20 feet high, 75 feet long, and with a lead-in wire 25 feet long. It is supported by two bamboo masts, each with two guys. Each mast consists of two sections coupled together. The ground system is either a counterpoise or mats. There are two mats made of coarse copper-wire mesh, each being 9 by 1⅜ feet. The counterpoise consists of two heavily insu-

lated wires each 75 feet long. The essential electrical constants of the antenna are, approximately: Inductance, 0.037 millihenry; capacity, 0.000131 microfarad; fundamental wave length, 130 meters; resistance, 50 ohms.

DESCRIPTION OF OPERATING CHEST.

4. The radio equipment is contained in a chest which is shown in figures 1 and 2. Figure 1 shows the front and end view; figure 2 shows the top and other end. The chest weighs approximately 24



pounds, and has no projections when closed for transportation, and is furnished with a carrying strap. The dimensions are 15½ by 6 by 13 inches high. The chest is divided into two separate compartments. The lower compartment, hinged at the back and fastened at the front, contains the telephone receiver, cords, tools, and spare parts. The upper compartment, which is divided by a shelf, contains the necessary condensers, inductances, switches, etc., of the set. A canvas flap folds down over the front of the case in order to protect it. The top of the box is hinged so as to give ready access to the apparatus which is most liable to need adjustment. All transmitting and receiving adjustments can be made on the outside of the chest, except changing the transmitting wave length.

Transmitter.

5. The transmitter is a 50-watt quenched-spark set with an open type of gap energized from a 10-volt storage battery by a special buzzer transformer. The inductances of the primary and secondary of the oscillation transformer are conductively coupled and are vari-

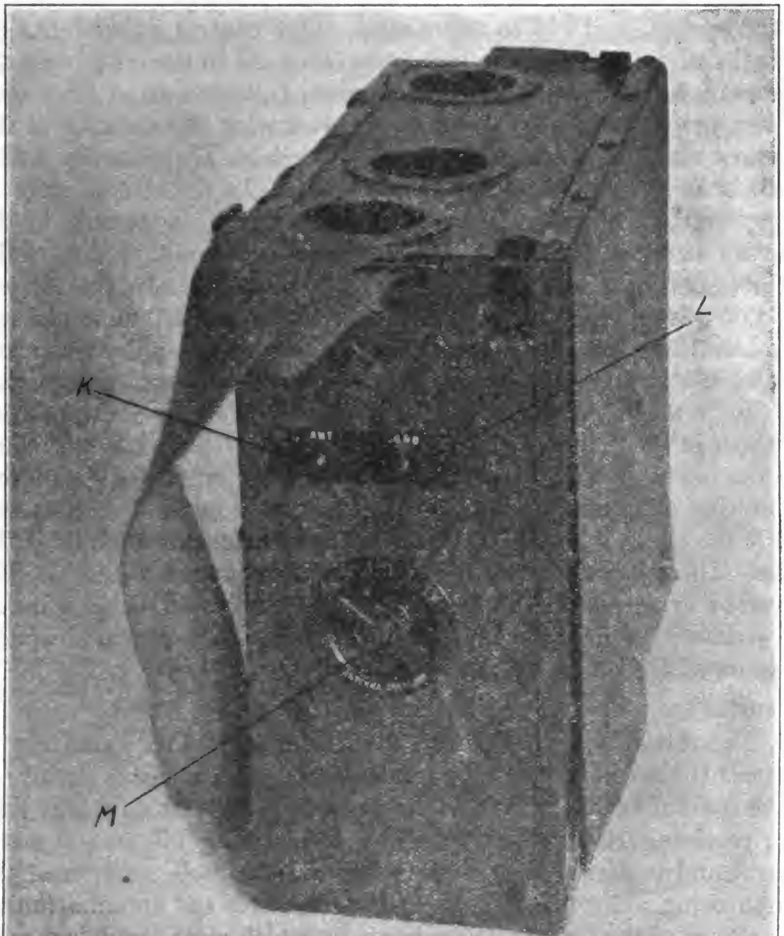


FIG. 2.

able in six steps controlled by one switch known as a "wave-change" switch. There is also a variable antenna tuning inductance of about 11½ turns in the secondary so that it can be exactly adjusted to resonance with the primary. A coupling switch controls the amount of inductance common to both the primary and secondary, and thus allows the coupling to be varied. The minimum coupling is at "1"

and the maximum coupling is at "6" on the coupling handle scale. A Weston thermoammeter is in the antenna to ground circuit and indicates the antenna current.

Receiver.

6. The receiver is inductively coupled with variable coupling. It has three overlapping scales of wave length; 100 to 200 meters, 150 to 300 meters, and 275 to 550 meters. One control switch changes both the primary and secondary from one scale to the other. In the shortest scale of wave lengths the switch throws a fixed mica condenser and a variable inductance in series with the antenna in the primary, and at the same time throws a variable air condenser and a small inductance in series in the secondary. In the middle scale of wave lengths the switch throws only the variable inductance in the primary in series with the antenna, and in the secondary throws the variable condenser and more inductance in series. In the longest scale of wave lengths the switch throws the variable inductance and an added inductance in series with the antenna, and in the secondary throws the variable condenser and still more inductance in series. It is to be noted that exact tuning is accomplished by a variable inductance in the primary and by a variable condenser in the secondary circuits. The detector furnished with the set is galena (lead sulphide) but other similar crystal detectors can be used. It is mounted inside the chest, with a control for adjustment on the outside of the chest. The coupling between primary and secondary of the receiver is varied by means of the secondary inductance coil rotating inside the primary inductance coil. Figure 3 shows a schematic wiring diagram of the set.

Circuits.

7. Referring to figures 1 and 2, A is the antenna ammeter; B controls the secondary tuning condenser of the receiving circuit; C is the control switch with contacts providing for transmitting; testing; receiving 100 to 200 meter waves; receiving 150 to 300 meter waves; and receiving 275 to 550 meter waves; each position of the switch being appropriately marked; D controls the antenna tuning inductance of the transmitting circuit by which exact resonance with the primary is obtained; E controls the coupling between the primary and secondary of the receiver circuits; F controls the primary tuning inductance of the receiver; G is the jack for telephone or amplifier plug; H is the crystal detector control; I is the key; J is the jack to receive the plug leading to the battery; K and L are the terminals for the antenna and ground wires respectively; and M controls the coupling between the primary and secondary of the transmitter. Figures 5 and 6 are labeled similarly to figures 1 and 2. Figures 1 and 2 show the control handles; figures 5 and 6 show the actual apparatus.

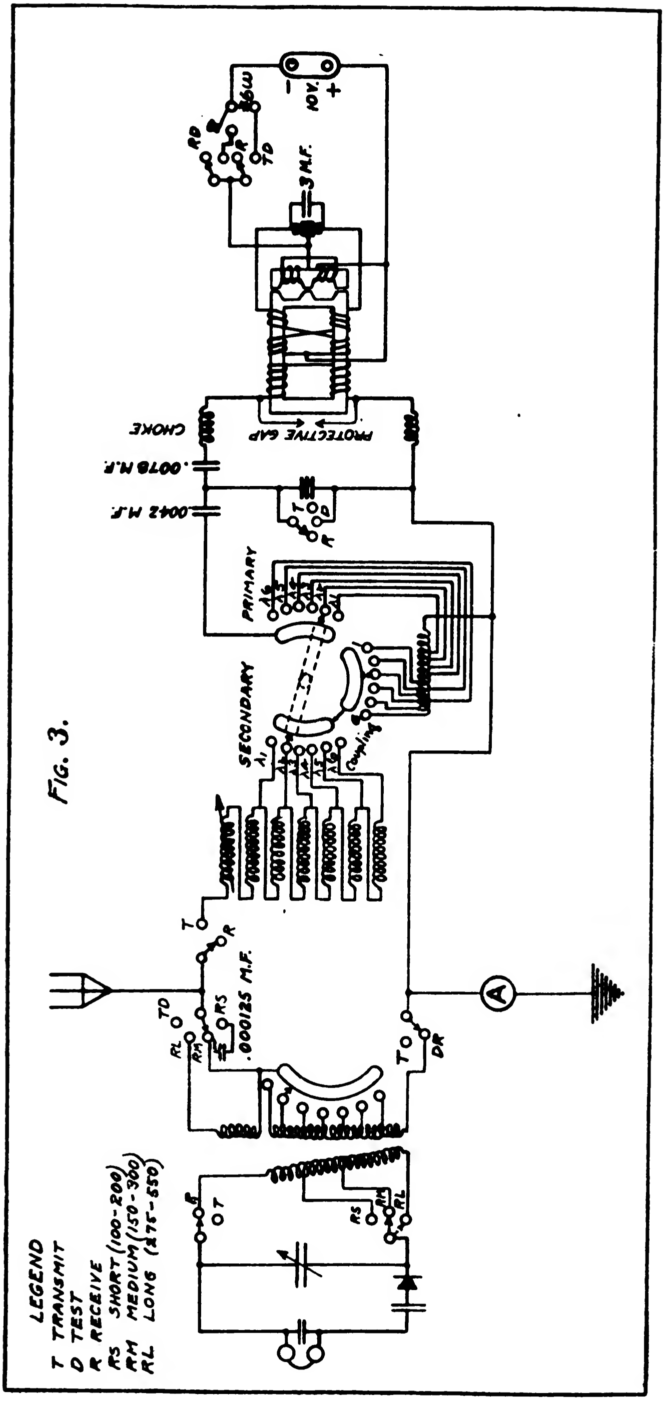

LEGEND
T TRANSMIT
D TEST
R RECEIVE
RS SHORT (100-200)
RM MEDIUM (150-300)
RL LONG (275-550)
PRIMARY
SECONDARY
Coupling
CHOKE
PROTECTIVE GAP
.0018 M.F.
.0042 M.F.
.000125 M.F.
3 M.F.
10V.

FIG. 3.

Control Switch.

8. The control switch is a multicontact switch which makes connections between silver contacts as shown in figure 4. The arrows in the upper part of the diagram show the connections made when the switch is in the position shown immediately below each part. The legend on the diagram shows the purpose of each contact. The contacts and connections are protected against short-circuit by dirt or occasional drops of rain by a shield of xylonite, a noncombustible material resembling celluloid.

Buzzer.

9. The buzzer transformer is a special buzzer having two primary windings wound so as to give opposite magnetic effects when carrying current. It uses about 5 amperes at 10 volts. By means of a

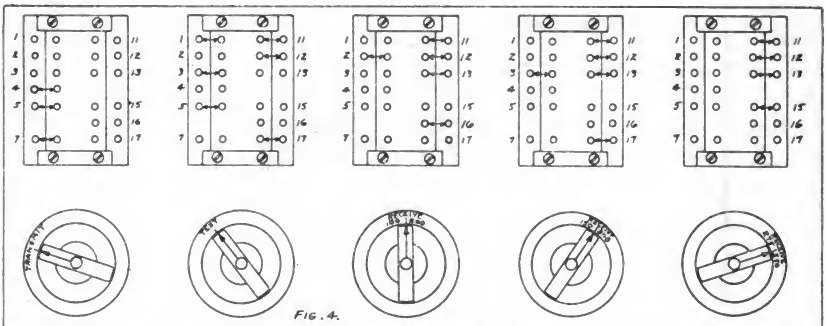


FIG. 4.

CONTACT NO.	FUNCTION	CONTACT NO.	FUNCTION
1	SHORT CIRCUITS QUENCHED GAP TO PROTECT OPERATOR	11	CONNECTS GROUND TO RECEIVER PRIMARY (GROUND SIDE)
2	CONNECTS SHORT WAVE SECONDARY TAP TO RECEIVING CONDENSER	12	CONNECTS BEGINNING OF SECONDARY COIL TO RECEIVING CONDENSER
3	CONNECTS MEDIUM WAVE SECONDARY TAP TO RECEIVING CONDENSER	13	CONNECTS LONG WAVE SECONDARY TAP TO RECEIVING CONDENSER
4	CONNECTS BATTERY TO BUZZER THROUGH KEY	15	CONNECTS ANTENNA TO LONG WAVE PRIMARY RECEIVING TAP
5	CONNECTS BATTERY TO BUZZER THROUGH RESISTANCE	16	CONNECTS ANTENNA TO SHORT WAVE PRIMARY RECEIVING TAP
7	CONNECTS ANTENNA TO TRANSMITTING LOADING COILS	17	CONNECTS ANTENNA TO MEDIUM WAVE PRIMARY RECEIVING TAP

vibrator which makes contact first with one primary and then with the other, there is produced in the secondary a maximum voltage in one sense followed by a maximum voltage in the other sense. The vibrator is actuated by the magnetism produced by the primary windings attracting and repelling a double electromagnet having opposite ends of the same polarity. This electromagnet is supported on a spring and has the vibrator arm and contacts attached to it. The vibrator is adjustable by means of set screws and has a frequency of approximately 360 vibrations per second. The peak voltage produced in the secondary is approximately 2,000 volts. There is a safety gap (P, fig. 6) mounted on the buzzer transformer to avoid puncturing the insulation should the spark gap be improperly adjusted.

Key.

10. The key is shunted by a 6-ohm resistance which allows enough current to pass so that the vibrator of the buzzer transformer is

kept in motion in the intervals between dots and dashes. The key contacts are of silver, which has excellent spark-quenching properties. Because of the shunt resistance and the silver contacts, the key breaks the current practically without sparking. The tension of the key spring is adjustable within certain limits. It can be increased by turning the screw just below the bottom of the key in a clockwise direction. It can be decreased by turning the screw in the opposite direction.

Spark Gap.

11. The spark gap has three silver plates separated by mica gaskets or separators 5 mils (0.005 inch) thick and the sparking occurs uniformly around the edges of the plates. The open type of gap is used, as it permits the operator to view the gap in operation and detect any irregularity in the spark or failure of the gaskets, and has the additional advantage that a punctured gasket can be easily replaced in the field. The gap is protected against being accidentally short-circuited by particles of dirt or occasional drops of rain by a shield of xylonite. The plates and separators can be removed after unscrewing the thumb nut. A view of the operating chest with front panel removed is shown in figure 5. A part of the front panel appears at the right.

SETTING UP THE SCR–105.

Antenna and Ground Installation.

12. The 75-foot antenna wire should be stretched out on the ground with the 25-foot lead-in wire in either of two positions, depending upon the use to which the set is to be put: (1) For general use the antenna may lie in any direction and the lead-in may be at either end of the antenna, but (2) for directional work the antenna must be in line with the direction of the distant station with the lead-in nearest that station. The mast sections should be coupled together, using two couplers on each mast, so as to give two masts each with a length over all of 20 feet. Lay one mast at each end of the antenna, along the antenna wire, and with the tops of the masts at the ends of the wire. Screw the mast cap insulators into the masts and attach the antenna insulators and guys to the caps. Drive two ground stakes near each mast, one on each side of the line of the antenna wire, about 10 feet beyond the ends of the antenna and 40 feet apart; and attach the guys to the stakes. Next raise one mast into position, placing the foot of the mast so that the strain from its guys and the rest of the antenna on the ground will keep it nearly upright. Then raise the other mast in a similar way, placing it so that there is sufficient tension on the antenna wire to keep it nearly horizontal. If necessary, straighten up both masts, tighten

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the guys, etc. If there is sufficient personnel, both masts can be raised at the same time and the guys tightened immediately after. In raising the antenna, handle the mast in such a way that the stress will be along the mast and not a bending one. For details in raising this antenna and for general information on antennas, see Radio Communication Pamphlet No. 2.

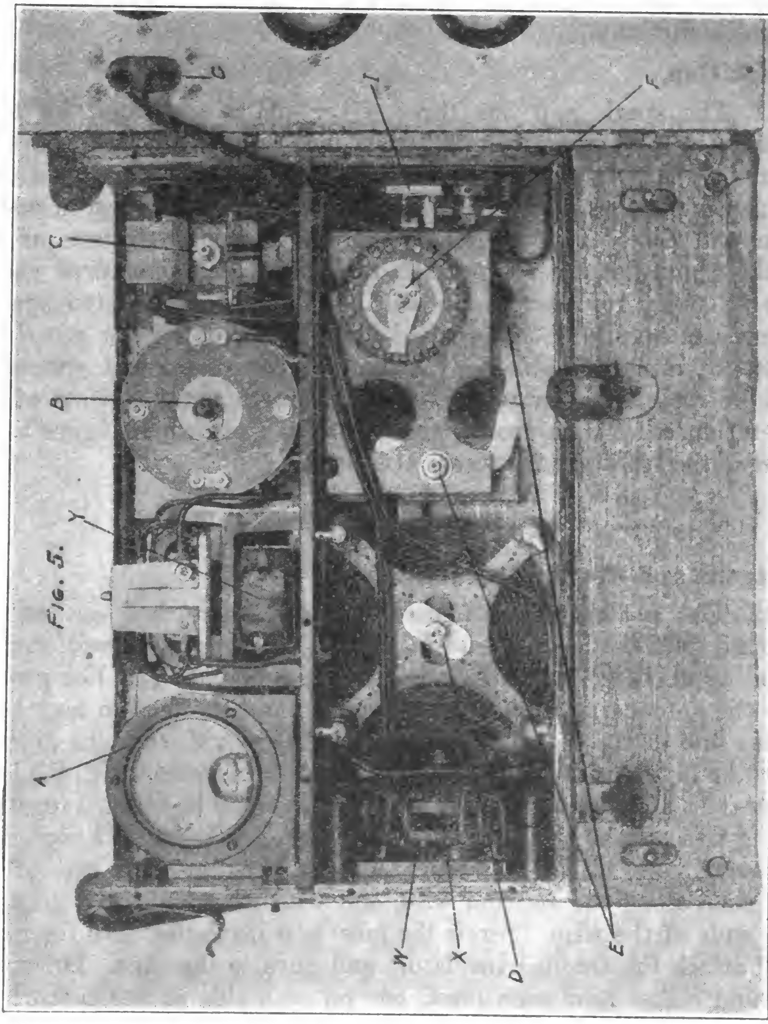


FIG. 5.

13. Whether the ground mats or the counterpoise is to be used depends upon the character of the ground, and the time available for installation. If it is possible to get a good ground, it is preferable to use the mats. The two mats should be connected in series and buried a few inches below the surface of the ground and the covering earth well tramped upon them. If the ground is dry or rocky or if the time available for installation does not permit of making

a good ground with the mats, the counterpoise should be used. When using the counterpoise, the two wires should be spread out at an angle of about 60° in such a manner that the antenna wire, if laid on the ground, would bisect the angle. The two counterpoise wires are connected electrically at the angle made by them.

14. Having decided which ground system to use, for general work (nondirectional) place the operating chest on a dry place underneath the antenna wire and if the ground mats are to be used put them also under the antenna and extend them away from the chest. If the counterpoise is used the angle of the wire should terminate near the operating chest, the wires being extended under the antenna and in the same general direction. For directional work the operating chest is placed outside the masts as far away as the lead-in wire will permit in the direction of the other station. Be sure that the lead-in wire does not touch the mast, as otherwise the antenna may be grounded thereby. The counterpoise is laid as described above, except that the wires should be extended away from the antenna. The mats should be buried beyond the operating chest. If additional counterpoise wires are available, they should be connected in parallel with the others. Similarly if other ground wires or plates are available they should be connected in parallel with the mats and in some cases the ground stakes may be used as additional ground connections. The better the ground connections or the greater the number of the counterpoise wires in general the sharper will be the tuning of both transmitter and receiver.

Necessary Connections.

15. Open the bottom compartment and remove the telephones and battery cords. Connect the antenna lead-in wire to the antenna binding post (K, fig. 2) and connect the mats or counterpoise to the ground binding post (L, fig. 2). Connect the battery cords to the proper terminals of the 10-volt battery and plug it in the battery jack (J, fig. 1), being sure to observe the proper polarity as marked on the jack and plug. Plug the telephone in the telephone jack (G, fig. 1). Pull down the key lever (I, fig. 1) until it snaps into place at right angles to the box. If no amplifier is to be used and the set has been properly adjusted, it is now ready to operate. If an amplifier is to be used, instructions for its use are contained in Radio Communication Pamphlet No. 9.

OPERATION OF THE SET.

To Transmit.

16. Raise the cover of the chest and move the wave-length lever (N, fig. 6) to the wave length desired. The upper edge of the slide *must be just below the white line* which is under the wave-length figure. This position must be exact, as otherwise the movable con-

tact will short-circuit turns on the primary coils (shown at W in fig. 5) and will not give the wave length desired. Set the control switch (C, fig. 1) in the "transmit" position. The buzzer should start vibrating although the key is not depressed, but there will be no spark at the spark gap (O, fig. 6). If the buzzer does not start vibrating, the set is not in adjustment. (See paragraphs 23 to 27, inclusive, on care and adjustment of the set.) Now set the antenna-coupling handle (M, fig. 2) to the maximum coupling for all wave lengths except 150, when it should be set one step lower than the maximum coupling. The coupling control is marked from "1" to "6"; the position at 1 gives the minimum coupling; that at 6 gives the maximum coupling. In setting the coupling be sure that the two index marks form a straight line. The coupling coil is shown at X in figure 5. Press the key and tune with antenna-tuning inductance (D, fig. 1) until the antenna ammeter shows the highest reading. Lower the antenna coupling one step and retune. Do this progressively until you are using the lowest possible antenna coupling that gives sufficient antenna current. The set is now ready for transmission. Under average field conditions the antenna current will be from 0.4 to 0.5 ampere and larger for the shorter wave lengths than for the longer ones.

To Receive.

17. Turn the control switch (C, fig. 1) to the "test" position. In this position a small current keeps the buzzer in vibration so as to serve as a testing buzzer for the detector. Adjust the detector by moving the detector adjustment (H, fig. 1) until a sensitive point has been found and the note of the buzzer is clearly heard in the telephone. In passing from transmitting to receiving, this test should also be made, as any previous adjustment is liable to have become disarranged. If the wave length to be received is known, the approximate setting of the tuning elements in the receiving circuits is shown in the following table:

CONTROL SWITCH SET AT "RECEIVE 150-300."

Wave length.	Ground mat.			Counterpoise.		
	Primary tuning inductance.	Secondary tuning condenser.	Receiver coupling.	Primary tuning inductance.	Secondary tuning condenser.	Receiver coupling.
150	13	2	40	13	1	60
180	17	5	80	13	4	35
210	19	5	30	13	6	25
240	16	6	30	19	8	25

CONTROL SWITCH SET AT "RECEIVE 275-550."

300	14	5	40	12	1	25

18. The above table is only approximate and will vary somewhat for each set. A table extending the wave lengths throughout their whole range should be made for each set. The table should be printed on a card and fastened to the inside cover of the operating chest. It saves much time in operating. It must be remembered that the table is only strictly accurate for the exact antenna used in compiling the table.

19. As soon as the signals are picked up, make slight adjustments of the tuning, coupling, detector, etc., until the loudest possible signals are obtained with the loosest possible coupling, that is, with the "receiver coupling" (E, fig. 1) as near the "minimum" as possible. Under these conditions any interference from other wave lengths will be reduced as much as possible with this set. The most important receiver adjustments are the sensitivity of the detector and the tuning of the secondary condenser. In a few cases the same wave length can be received with the "control switch" in two successive positions, near the end of the scale in the first position, and near the beginning of the scale in the second position. This is due to the overlapping of the scales and in many cases one adjustment is much better than the other.

20. If the wave length is unknown, signals may be found by trial somewhat as follows: Set the "control switch" (C, fig. 1) on the "275–550" meter range; the "receiver coupling" (E, fig. 1) at "maximum"; and the "secondary tuning condenser" (B, fig. 1) near the zero end of its scale. Tune with the "primary tuning inductance" (F, fig. 1) over its scale. If signals are not picked up, set the "control switch" on the "150–300" meter range and repeat. If necessary, repeat with the "control switch" on "100–200." When hunting for signals, make sure that the detector is kept in a sensitive condition by occasionally turning the "control switch" handle to the "test" position and then turning it back to its former scale position. As soon as the signals are heard, loosen the coupling, retune both circuits, etc., as stated in the previous paragraph.

Wave Length Measurements.

21. The transmitting and receiving wave lengths can be measured by a wave meter. Reference, Radio Communication No. 28. In measuring the wave lengths of the primary of the transmitter, that is without an antenna and ground connected to the set, the plane of the wave-meter coil should be parallel to the lower left end of the box near the antenna-coupling adjustment in order to couple with the primary coil. In measuring the wave lengths radiated by the set, the wave-meter coil may be brought near the antenna or if necessary parallel to the back of the box immediately behind the antenna-tuning-inductance adjustment in order to couple with the antenna

coils. The receiver wave lengths are measured by the usual methods. In every case, however, the usual precautions of loosely coupling the meter to the set must be observed so as to avoid any appreciable reaction between the two circuits.

Amplifier.

22. When an amplifier is used with the set in receiving, it is connected by a cord to the telephone jacks. The set itself contains a detector and should the amplifier also contain a detector, the latter one should not be used. The BC–101 amplifier, which will be most commonly used with the SCR–105, consists of a vacuum tube detector and a two-stage amplifier. A switch is provided on this amplifier which permits the detector being cut out of the circuit. It should be so cut out when used with the SCR–105 set. Radio Communication Pamphlet No. 9 will contain operating instructions for the BC–101 amplifier.

CARE AND ADJUSTMENT OF THE SET.

23. The operating chest should be kept dry and clean. Do not store it in a damp place, as it is impossible to make a set of this type waterproof. If it has been exposed to the rain it should be carefully wiped off and dried, but not exposed to direct heat. The battery cord is waterproof but the telephone cord is not. If the latter gets wet and short-circuits the telephones use another cord if available and in the meantime carefully dry out the wet cord, which will become operative again. If no other cord is available cut away very carefully the *outer* braid on the cord, making certain that the conductors are not injured and then separate them, thus removing the short-circuit. Do not subject the chest to unnecessary jars or rough treatment. The interior of the chest contains a great many parts packed in a small space and these are subject to derangement. The connection between the parts may also become loose if the chest is roughly handled. The detector crystal is mounted in a small casting of a low melting point alloy, known as Wood's metal. This is held by a screw in a post that is removable for convenience in renewing the crystals. Care must be taken to keep the sensitive surface dry and clean and not to scratch it in any way. The surface is sensitive only when it has been obtained from a *natural* fracture. Crystals should be separately wrapped in a paper wrapping and kept in the small box in the lower compartment. When not in use the key should always be folded into the end of the chest and the detector adjustment knob should always be pushed in flush with its plate.

Telephones.

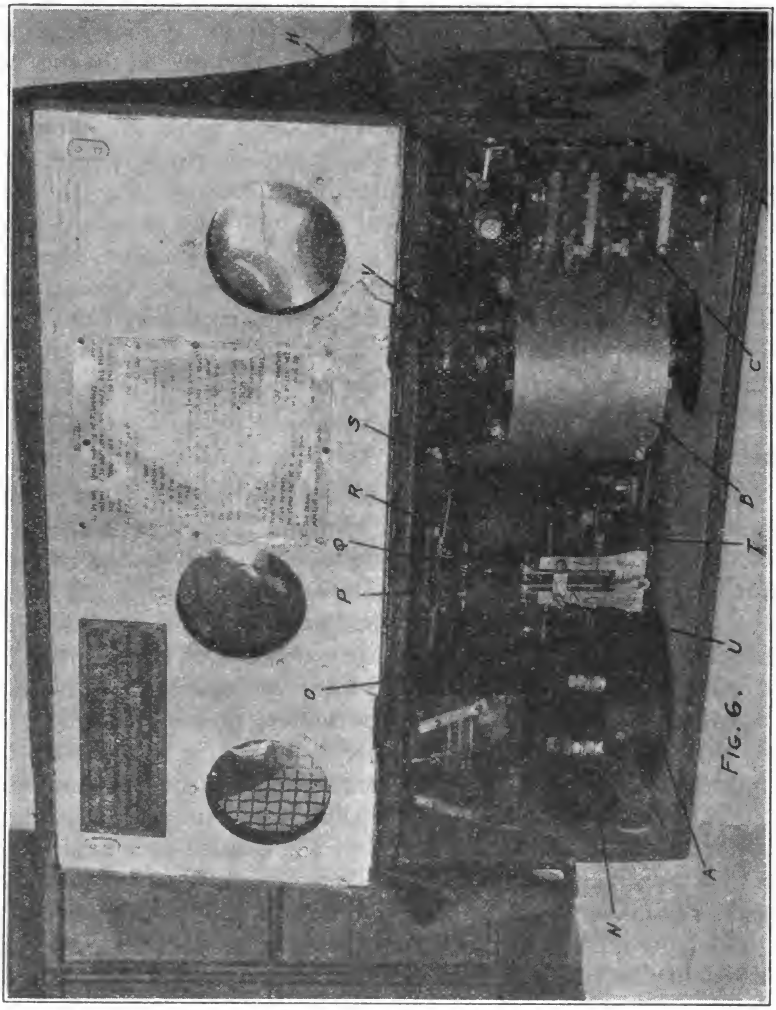
24. The telephone receivers must be carefully handled, special care being taken never to drop them and never to injure the diaphragm. If the latter is bent or dented the diaphragm may touch the pole pieces of the magnet and the magnetic attraction may be so strong that it will be held there, with the result that the telephone is "dead" although otherwise in perfect condition. In order to obtain the correct clearance under the diaphragm the poles of the magnet are ground *after assembly*, this being necessary as the standard parts can not otherwise be assembled with sufficient accuracy. For this reason the telephone should never be taken apart as it is certain that these adjustments will be disturbed. In putting away the telephones into the bottom compartment the following standard practice should be followed in order to protect the diaphragms and terminals: Place the two receivers with the faces of the caps parallel and together so that all access to the diaphragms through the openings in the caps is closed and then bind them in this position by winding the telephone cord around the outside of the headband, beginning close to the caps.

Buzzer Adjustments.

25. The adjustment of the buzzer requires patience and experience. Theoretically it is possible to adjust it so that there is no sparking at the contacts. Actually this is seldom attained, but it can be adjusted so that nearly sparkless operation obtains. In adjusting the buzzer it is well to do it under working conditions, i. e., in the field with the proper antenna and with the battery assigned to the set, but care must be taken not to cause interference to other stations. This interference can be avoided by using the loosest possible coupling between the antenna and primary circuits; that is, by setting the antenna coupling at 1. After the buzzer adjustment has been completed, be sure to return the antenna coupling to its correct position. In adjusting the vibrator, be sure that the control switch is in the "transmit" position, and then if it does not work when the key is pressed, *release the key instantly*, as otherwise the primary winding will be burnt out. With the vibrator working properly, it is the reactance of the primary winding that keeps the current down to its proper value, but with the vibrator stopped there is only a low resistance in circuit that will allow a very heavy direct current to flow. In transmitting, also, if the vibrator sticks, release the key instantly for the same reason.

26. The buzzer should vibrate when the "control switch" is in the "test" and also when it is in the "transmit" position, even when the key is not closed, but there should not be any spark at the spark gap under these conditions. When the key is pressed down the buzzer

should vibrate, and there should be a good spark at the spark gap. If it does not vibrate, do not under any circumstances add higher battery voltage. As shipped from the factory after inspection by the Signal Corps, the buzzer has been adjusted to give this operation. In general it will require very little adjustment when received.



27. Figure 6 is a view looking down into the set, showing the buzzer. The end of the vibrator with its double contacts is shown at Q. This vibrator is between two other fixed contacts symmetrically placed, one of which is labeled "R." The four contact tips are of platinum-iridium, which because of its hardness and the high temperature of its melting point makes the sparking much less than between other metals. The tips should have plane surfaces and be

parallel when contact is made. The play of the moving contacts should be about one one-hundredth of an inch. (The thickness of three sheets of this pamphlet is very nearly one one-hundredth of an inch.) After having been in service for some time, the contacts become roughened and should be cleaned. This is done with a fine file, which is a part of the equipment of the set carried in the lower compartment. The contacts should not be removed, but the locknuts loosened and the contacts unscrewed until the file can be introduced between them. It is seldom necessary to move these locknuts for any other purpose than cleaning. The two screws marked U in Figure 6 are for clamping the two adjustment screws with the black knobs marked S. The latter should never be turned without first loosening U, as otherwise their threads may be stripped. The black knobs are used in adjusting the opening between the fixed contacts, which must be such that the movable contact rests against one of the fixed contacts when no current is flowing, and so that the poles of the movable magnet, which is shown at T, Figure 6, do not hit the poles of the fixed magnet. If they do, the poles are liable to stick together. This condition will also prevent good contact at the vibrator points and will cause considerable sparking there. If a strip of paper can be passed between the poles when the buzzer is operating, the adjustment in this respect is good. If one of the poles hits, this can be remedied by *screwing* in the adjustment knob on the *opposite* side of the buzzer and *unscrewing* the knob on the *same* side until both pole tips are free.

Spark Gap.

28. The spark gap can be taken apart by unscrewing the thumb nut. When the sparking becomes localized at one or two points on the plate, unloosen the thumb nut and rotate each plate slightly on the mounting until the sparking is uniform again. If it is found impossible to get uniform sparking by this method, then the plates must be polished. This should be done by placing them face down on a sheet of fine emery or sand paper on a flat surface and rubbing them over the paper lightly, using a rotating motion. Great care must be taken not to polish only one part of the sparking surface, as this will decrease the thickness of the plate at this point, and hence may so increase the width of the gap that no sparks can pass. The thickness of each plate between its sparking surfaces is uniform to within less than half a thousandth of an inch. After polishing be sure that the particles of emery and metal dust are carefully cleaned off the plates, otherwise the emery may cut and puncture the mica gaskets. Care should be exercised in handling the gaskets in order to avoid cracking them. If a gasket fails replace it with a new one.

Cautions.

29. In handling and adjusting the set:

Don't subject it to rough usage. To do so will damage the instruments therein.

Don't try to adjust the ammeter. It is used to show comparative values of the antenna current and not exact values.

Don't use a closer coupling in transmitting than is absolutely necessary. The radiated wave will be very broad with a close coupling.

Don't connect more than 10 volts to the buzzer. A higher voltage will burn it out.

Don't expect the set to operate if the storage batteries are near discharge. It takes just 10 volts for the buzzer; less than 10 volts will not operate it.

Don't tinker with the buzzer adjustments when once properly adjusted. The buzzer is very easily thrown out of adjustment.

Don't hold the key down continuously for more than 10 seconds, and

Don't transmit continuously with the set, and

Don't fail to release the key instantly if the vibrator sticks. The buzzer will burn out if these three precautions are not observed.

Don't use a gasket in the spark gap thicker than the one provided. The voltage necessary to jump a longer gap will puncture the insulation and the transmitter note will be made rough or irregular.

Don't carry any parts in the upper compartment; use the bottom compartment.

Don't use a different antenna than the one prescribed. The variable inductance in the secondary of the transmitter is not great enough to permit any marked departure from the characteristics of the antenna prescribed.

Don't fail to study your set and to learn the causes of failure and their remedies. Learn also the appearance of the spark and the characteristic sound of the set when it is operating properly.

Don't fail to disconnect the battery when leaving the set for any purpose.

Don't fail to fasten both snap-catches on the bottom compartment when closing station.

THEORY.

Buzzer—Electric and Magnetic Circuits.

30. The buzzer transformer used in this set combines the principles of the induction coil and the resonance transformer. The moving part of the buzzer (the armature) is designed and adjusted to have a period of approximately 360 cycles per second. In order to insure sufficient pressure when contact is made, an electromagnet is used instead of a permanent magnet as it produces a stronger magnetic field.

This electromagnet is wound two ways upon its core from the center of the core, thus giving an electromagnet having both ends of the same polarity, with consequent poles in the middle of the core. This core is of steel and not laminated as the magnetic flux in it is nearly constant. There is a double primary in the transformer, one being wound so as to produce a magnetic flux opposite in direction to that of the other. The current passes through each primary successively as the armature successively makes one contact and then the other. The core of the transformer proper is built up of laminations of silicon steel with three projections, one near either end of the electromagnet and the third one near its consequent poles, which are along the axis of the vibrating system. When a current flows through a primary winding, a magnetic flux is established in the transformer core. Magnetic circuits resulting from the magnetic leakage from the projections pass through either end of the electromagnet and produce a torque on it. The electrical circuits are so connected and wound in the primary coils that the torque, produced by the magnetic flux established by the electric current passing through the circuit made by contact on one side, is such as to move the armature to the other contact. When the other contact is made, the resultant magnetic flux and therefore the resultant torque is changed in direction, thus pulling the armature back to make the first contact. There is only a single secondary winding which however is wound in sections, four on each leg of the core, thereby giving greater protection against high and sudden electromotive forces.

31. As a result of the action described in the previous paragraph, the magnetic flux made by the primary circuits and passing through the core of the transformer is periodically established in one direction, wiped out, and then established, with the same intensity, in the opposite direction. The electromotive force induced in the secondary therefore is symmetrical above and below the zero line. As a result of this symmetrical current induced in the secondary, and the precise and regular vibration of the armature giving regularly the corresponding changes in the induced current, the tone produced by the set in transmission is of good quality.

Vibrator.

32. In order to secure firm contact with a high rate of vibration, the armature was necessarily given a considerable mass, and a short distance of travel from contact to contact (about 0.01 inch). It is mounted on a tempered steel spring, silver plated, to prevent rusting, with an adjustable tension that is set at the time of assembly to give about 360 vibrations per second. The frequency of vibration of the armature is determined not only by the distribution of mass of the moving parts, its distance of travel between contact points, and its

method of suspension, but also by the constants of the electromagnetic circuits which actuate it. In this buzzer transformer, all parts are coordinated so as to give a frequency of approximately 360 vibrations per second.

Application of Resonance Transformer.

33. If no provision were made to diminish the arc resulting from self-induction, made at the breaking of the contacts, the arc would be considerable and would wear out the contact points in a short while, besides greatly reducing the efficiency of the apparatus.

34. To effect the reduction of this arc the primary and the secondary of the transformer are built so that their electrical constants are such as to give them the same natural (audio) frequency which is also the mechanical frequency of the vibrator. Thus the principle of the resonance transformer is used in the buzzer transformer. The design of the transformer involves the consideration of the electric and magnetic properties of each circuit separately, and the reflected value of one circuit as it appears in the other. Thus the capacity of the secondary condenser is reflected into the primary circuit in proportion to the inverse square of the ratio of transformation. With a ratio of primary to secondary of 1 to 175 the secondary series condensers of 0.0027-microfarad capacity appear in the primary increased 30,000 times or as 83 microfarads. The 3-microfarad condenser placed (shown at Y in fig. 5) across the contact points of the primary circuit is used to help establish the proper LC value of the primary. The leakage reactance of the magnetic circuit is an important factor in this consideration, as the magnetic leakage between the primary and secondary and from the projections of the core of the transformer is high.

35. Because of the resonance feature of the transformer the leads from the storage battery to the set box must not vary greatly in electrical length from those furnished with the set. Very long leads that are inclosed within an iron conduit should never be used on account of their high inductance. The leads from the battery are a part of the primary circuit of the transformer and any great change in their electrical length changes the LC value of this circuit and hence will throw it off the proper resonance point. Such conditions as described in this paragraph are, however, rarely met with in field service.

36. The action of the resonance transformer in reducing the arcing at the contact may be explained as follows: The time-voltage curve of electromotive force induced in the secondary lags behind the time-ampere curve of the inducing current in the primary. Thus when the primary current has reached its maximum value (i. e., sufficient to break the contact by its torque action) the electromotive

force in the secondary has not reached a value great enough to break down the quenched spark gap. At the instant the break is made in the primary there is released the energy of a large self-induction in the primary. The rising electromotive force of the secondary is not up to the final value that it attains because of its resonance and therefore keeps on mounting. The energy taken by this rising electromotive force is absorbed from the primary, thereby decreasing at the break the energy that would otherwise appear there and cause sparking. Also the electromotive force of the secondary rises higher because of this absorption of energy at the time of the break. It is the resonance feature of the transformer which causes the secondary electromotive force to rise higher at the primary break than it would do if it were an ordinary induction coil.

37. The condenser across the contacts also absorbs some of the energy of self-inductance. This condenser will then discharge with high frequency oscillation, thus dissipating the energy of the primary circuit and having the usual effect of quenching the arc.

38. The absorption of energy from the primary circuit and the quenching of the arc makes the arc a small one of short duration. When the electromotive force of the secondary reaches a value high enough to break down the quenched spark gap, the arc at the contacts of the buzzer has been extinguished and hence the circuit in the primary is not complete through the contacts and will not absorb appreciable energy from the current flowing in the secondary.

39. The constants of the circuits affecting resonance vary with the frequency of the alternations in the transformer. Thus the transformer works best on 360 cycles. If the current actuating the buzzer is entirely stopped, the buzzer comes to rest. The making of the circuit starts the buzzer which must pass from a zero frequency to the 360 frequency, and therefore the efficiency of the transformer during this time is very low. The transmission of dots and dashes involves many stoppings and startings of the current. Because of this fact, the key is shunted by a resistance of such a value that it

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NOTE.—It may be possible that the 3-microfarad condenser across the contacts of this set is charged by the battery to a higher potential than the battery furnished. A circuit that will oscillate on discharge will also oscillate on charge. The equation for charging a condenser is:

$$e_1 = e\left\{1 - \epsilon^{-\frac{r}{2L}t}\left(\cos\frac{q}{2L}t + \frac{r}{q}\sin\frac{q}{2L}t\right)\right\}$$

when $q = \sqrt{\frac{4L}{C} - r^2}$ and the other symbols are those as commonly used. Thus if the damping factor $\left(\frac{r}{2L}\right)$ is not large, the e_1 value will rise to greater than unity in the quadrants in which $\cos\frac{q}{2L}t$ is negative. The oscillating electromotive force damps down to the electromotive force of the charging battery. Because of the brief time in which contact is made, the circuit may be broken before the oscillating condenser electromotive force has been damped down to its steady value.

allows the passage of a current just of sufficient strength to actuate the buzzer at its proper frequency, but not strong enough to build up an electromotive force in the secondary which will break down the spark gap.

Choke Coils.

40. In order to protect the buzzer secondary windings from puncture by the radio frequency oscillations from the primary oscillating circuit, two heavily insulated choke coils of high inductance (0.35 henry) have been inserted in the leads of the buzzer secondary, one of which is shown at V in figure 6. The protection which such a coil can give by its inductance reactance (2 Π N L) is shown by the following: At a frequency of 1,000,000 cycles per second, corresponding to the 300-meter wave length, the reactance is 2,000,000 ohms. Thus each coil offers such a high impedance to the radio frequency oscillations as to reflect them back into the oscillating circuit and thus protect the buzzer windings. These same coils, however, offer only a slight impedance (800 ohms at 360 cycles) to the low-frequency current from the buzzer secondary that charges the oscillating circuit condenser.

Secondary Condensers.

41. In the schematic wiring diagram (fig. 3) it will be noticed that in the circuit of the buzzer secondary there are two condensers in series, one of 0.0078 microfarad, and the other of 0.0042 microfarad. The resultant capacity is 0.0027 microfarad, which had previously been found necessary for resonance at the buzzer frequency of 360 cycles per second, but too small for the capacity of the primary oscillating circuit. For this reason two larger capacities were used in series, one of 0.0042 microfarad as desired for the primary circuit and the other of 0.0078 microfarad, to give the correct resultant capacity as above. Both condensers are of mica, with sections in series to withstand the high potentials of the buzzer secondary circuit and the primary oscillating circuit, and they are sealed with a suitable wax to exclude the air and moisture.

Reception of Short Wave Lengths.

42. For the best reception of short wave lengths, that is with the control switch in the 100 to 200 position, it has been found necessary to short-circuit the turns needed for long waves. This is accomplished at contact 13 in figure 4 as noted in the legend giving the function of each contact. The purpose of the short circuit is to eliminate the so-called "dead-end" effect in which inactive turns absorb energy from the useful turns which would otherwise operate the detector.

Telephone Circuits.

43. In the schematic wiring diagram (fig. 3) it will be noticed that in the telephone circuit of the tuned secondary receiving circuit there is an extra condenser connected between the detector and telephones. This condenser is necessary however as will be seen from the following circumstances—if by mistake the 10-volt battery plug instead of the telephones is connected to the telephone jack, and if at the same time the detector arm or contact spring makes good connection with the detector post, then the 10-volt battery is applied directly to the windings of the secondary circuit. As a result either the windings will be burnt out or the battery will be run down. By the use however of a comparatively large condenser connected in series both the radio frequency currents and the audio frequency pulsating telephone currents will be permitted to flow freely, but the steady battery current will be completely stopped.

44. The telephones are wound with many turns of fine wire, and hence to a high resistance (2,500 ohms) as is necessary for use with crystal detectors. The windings are protected against high potentials by a small spark gap at their terminals. The *impedance* of the windings at the standard telephone testing frequency of 800 cycles per second, with the diaphragm clamped, is about 10,000 ohms. The *motional* impedance, however, will be different, particularly near the natural frequency of the diaphragm, which is between 700 and 1,000 cycles per second.

Efficiency.

45. The over-all efficiency of the set is about 20 per cent; that is, 20 per cent of the battery output is delivered to the antenna. Thus the battery output is 5 amperes at 10 volts or 50 watts; and the antenna input is 0.45 ampere in a 50-ohm circuit or 10 watts. The efficiency is therefore 20 per cent.

Parts List.

46. The SCR–105 set is complete only when it includes all of the items in the parts list given below. In ordering complete sets it is not necessary to itemize the parts but only to specify "1 set, radio telegraph, Type SCR–105." If all parts listed under a group heading, as "1 equipment, Type RE–12, radio," are desired, it is not necessary to itemize the parts but simply to specify the name of the equipment as given in the parts list. In ordering parts of the set use only the names and type numbers as given below. This list supersedes all others issued prior to the date of this pamphlet (November, 1921).

PARTS LIST OF SCR-105 SET.

[Arranged by equipment.]

1 Equipment, Type PE-11; power:
- 3 batteries Type BB-23—storage, lead; 10 volts, 20 ampere-hours; 1 in use, 2 spare.

1 Equipment, Type RE-12; radio:
- 2 contacts, Type CN-8—buzzer, movable contact; 1 in use, 1 spare.
- 4 contacts, Type CN-9—buzzer, fixed contacts; 2 in use, 2 spare.
- 2 contacts, Type CN-13—control switch, spring with silver contact; pairs with contact Type CN-14; 1 in use, 1 spare.
- 2 contacts, Type CN-14—control switch, bracket with silver contact; pairs with contact Type CN-13; 1 in use, 1 spare.
- 2 contacts, Type CN-15—key, screw with silver contact; pairs with contact Type CN-16; 1 in use, 1 spare.
- 2 contacts, Type CN-16—key, spring with silver contact; pairs with contact Type CN-15; 1 in use, 1 spare.
- 3 contacts, Type M-14—detector, spring contact; 1 in use, 2 spare.
- 1 cord, Type CD-95—10-volt leads, battery to operating chest.
- 1 cord, Type CD-96—amplifier leads from operating chest to amplifier.
- 4 crystals, type DC-1—detector, mounted galena; 1 in use, 3 spare.
- 1 file, 3½ inches, single cut, flat needle.
- 1 head set, Type P-11—used with amplifier.
- 1 head set, Type HS-11—used with operating chest.
- 1 operating chest, Type BC-53-A.
- 1 plier, pair, side cutting, 4-inch.
- 1 screw driver, 1½-inch blade, 1/8-inch tip.
- 6 separators, Type IN-9—mica, for quenched gap; 2 in use, 4 spare.
- 1 wrench, Type TL-100—buzzer contacts.

1 Equipment, Type A-16—antenna:
- 1 bag, Type BG-12—carrying counterpoise, stakes, etc.
- 250 feet cord, sash, 5/32-inch diameter—guy ropes.
- 2 counterpoise, Type CP-5—each 75 feet counterpoise wire.
- 6 couplers, Type FT-2—coupling mast sections; 4 in use, 2 spare.
- 6 fasteners, Type FT-9—for guy rope; 4 in use, 2 spare.
- 1 hammer, 2-pound, 2-face.
- 4 insulators, Type IN-5—for antenna; 2 in use, 2 spare.
- 3 insulators, Type IN-6 or IN-7—mast cap; 2 in use, 1 spare.
- 6 mast sections, Type MS-5—bamboo; 4 in use, 2 spare.
- 2 mats, Type MT-2—ground; connected in series.
- 3 pins, insulator, Type FT-3—for insulators IN-6 or IN-7; 2 in use, 1 spare.
- 1 pliers, pair, 6-inch combination.
- 7 reels, Type RL-3—2 for counterpoise; 1 for antenna; 2 for guys; 1 for spare wire; 1 spare.
- 1 roll, Type M-15—carrying mast sections, mats, etc.
- 6 stakes, Type GP-1 or GP-16—for guy ropes; 4 in use, 2 spare.
- 1 roll tape, friction.
- 250 feet wire, Type W-1—antenna, 75 feet; lead in, 25 feet; 150 feet spare.

1 Radio Communication Pamphlet, No. 25.

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SIGNAL CORPS PAMPHLETS.

[Corrected to October 1, 1921.]

RADIO COMMUNICATION PAMPHLETS.

(Formerly designated Radio Pamphlets.)

No.

1. Elementary Principles of Radio Telegraphy and Telephony (edition of Apr. 28, 1921), W. D. D. 1064.
2. Antenna Systems.
3. Radio Receiving Sets (SCR–54 and SCR–54–A) and Vacuum Tube Detector Equipment (Type DT–3–A).
5. Airplane Radio Telegraph Transmitting Sets (Types SCR–65 and 65–A).
10. Ground Telegraphy or T. P. S. (Types SCR–71; SCR–72; SCR–72–B).
11. Radio Telegraph Transmitting Sets (Types SCR–74; SCR–74–A).
13. Airplane Radio Telegraph Transmitting Set (Type SCR–73).
14. Radio Telegraph Transmitting Set (Type SCR–69).
17. Sets U. W. Radio Telegraph (Types SCR–79–A and SCR–99).
18. Listening-in Stations.
19. Two-Way T. P. S. Set (Type SCR–76–A).
20. Airplane Radio Telephone Sets (Types SCR–68; SCR–68–A; SCR–114; SCR–116; SCR–59; SCR–59–A; SCR–75; SCR–115).
21. Theory and Use of Wavemeters (Types SCR–60; SCR–61).
22. Ground Radio Telephone Sets (Types SCR–67; SCR–67–A).
23. U. W. Airplane Radio Telegraph Set (Type SCR–80).
24. Tank Radio Telegraph Set (Type SCR–78–A).
25. Set, Radio Telegraph (Type SCR–105), W. D. D. No. 1077.
26. Sets, U. W. Radio Telegraph (Types SCR–127 and SCR–130), W. D. D. No. 1056.
30. The Radio Mechanic and the Airplane.
40. The Principles Underlying Radio Communication (edition of May, 1921), W. D. D. No. 1069.

WIRE COMMUNICATION PAMPHLETS.

(Formerly designated Electrical Engineering Pamphlets.)

1. The Buzzerphone (Type EE–1).
2. Monocord Switchboards of Units Type EE–2 and EE–2–A and Monocord Switchboard Operator Set Type EE–64 (W. D. D. No. 1081).
3. Field Telephones (Types EE–3; EE–4; EE–5).
4. Laying Cable in the Forward Area (formerly designated Training Pamphlet No. 3).
6. Trench Line Construction (formerly designated Training Pamphlet No. 6–a).
7. Signal Corps Universal Test Set Type EE–65 (W. D. D. No. 1020).
10. Wire Axis Installation and Maintenance Within the Division (W. D. D. No. 1068).

TRAINING PAMPHLETS.

1. Elementary Electricity (edition of Jan. 1, 1921), W. D. D. No. 1055.
4. Visual Signaling.
5. The Homing Pigeon, Care and Training (W. D. D. No. 1000).
7. Primary Batteries (formerly designated Radio Pamphlet No. 7).
8. Storage Batteries (formerly designated Radio Pamphlet No. 8).

FIELD PAMPHLETS.

1. Directions for Using the 24-CM. Signal Lamp (Type EE–7).
2. Directions for Using the 14-CM. Signal Lamp (Type EE–6).
3. Directions for Using the Two-Way T. P. S. Set (Type SCR–76).
4. Directions for Using Airplane Radio Telegraph Transmitting Set (Type SCR–73).

SETS

UNDAMPED WAVE RADIO TELEGRAPH TYPES SCR-127 AND SCR-130

Radio Communication Pamphlet No. 26

(SECOND EDITION)

PREPARED IN THE OFFICE OF THE CHIEF SIGNAL OFFICER

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WASHINGTON, *January 21, 1921.*

The following publication, entitled "Sets, Undamped Wave Radio Telegraph, Types SCR–127 and SCR–130," is published for the information and guidance of all concerned.

[062.1, A. G. O.]

BY ORDER OF THE SECRETARY OF WAR:

PEYTON C. MARCH,
Major General, Chief of Staff.

OFFICIAL:

P. C. HARRIS,
The Adjutant General.

TABLE OF CONTENTS.

SETS, UNDAMPED WAVE RADIO TELEGRAPH,

TYPES SCR-127 AND SCR-130.

PURPOSES OF SETS.

These sets are designed to transmit and receive undamped wave radio telegraphy. The SCR–127 set is intended for communication between mounted organizations. The entire equipment is carried on pack animals. The SCR–130 set is intended for communication between organizations equipped with ample motor or wagon transport. The two sets have the same antennæ and set box, but differ in the means provided for transportation and in the source of electric current. They have sufficient power to assure communication between points 60 miles or less distant. Their transmitting wave-length range is from 550 to 1,100 meters; the receiving wave-length range is from 350 to 1,100 meters.

DESCRIPTION OF SETS.

Antennæ equipment.

The antenna equipment consists of a sectional mast, antenna wire, counterpoise wire, guy ropes, and ground stakes. The masts consist of 14 sections, each 4 feet 2 inches long. Including the coupling tube, the sections are 5 feet 2 inches over all. Ten sections are used for the mast itself, three sections for a tent furnished with the set, and one section is a spare. The standard antenna is of the umbrella type with six radiating wires, each 75 feet long, suitably insulated at the open ends and held as nearly horizontal as possible by guy-rope extensions 90 feet long, the outer ends of which are made fast to ground stakes. The standard counterpoise has six radiating insulated wires, each 90 feet long, laid out on the ground under the antenna wires. Both antenna and counterpoise wires are carried on hand reels for convenience in packing and quick reeling and unreeling in setting up and taking down the mast.

Shelter tent.

This tent is similar in dimensions and construction to the standard "common" wall tent issued by the Quartermaster's Department, but is made of lighter material and is not provided with ridge pole or uprights. In erecting the tent the extra sections furnished with the mast should be used as the ridge pole and uprights as follows: One mast section, one plug, and one extension piece for the ridge; and one

mast section, one extension piece with spike for each upright. This is shown in figure 3–A.

A device is provided for use in insulating the antenna when the shelter tent is used in damp weather, consisting of a square piece of sheet rubber with small marginal holes for lacing into the ventilator at either end of the tent, and a tube attached to the center for admitting the antenna lead. When in use, a sufficient slack should be left in the antenna lead to form a drip loop outside of the tent, and if found necessary a piece of heavy insulated wire can be used as a leading-in wire.

Set box.

The set box contains the vacuum tubes, condensers, and other parts necessary in a radio set. The front of the box forms a shelf for the key and for writing when the box is open. The box is supported on removable legs. Figure 1 shows the panel with the front of the box lowered to the operating position.

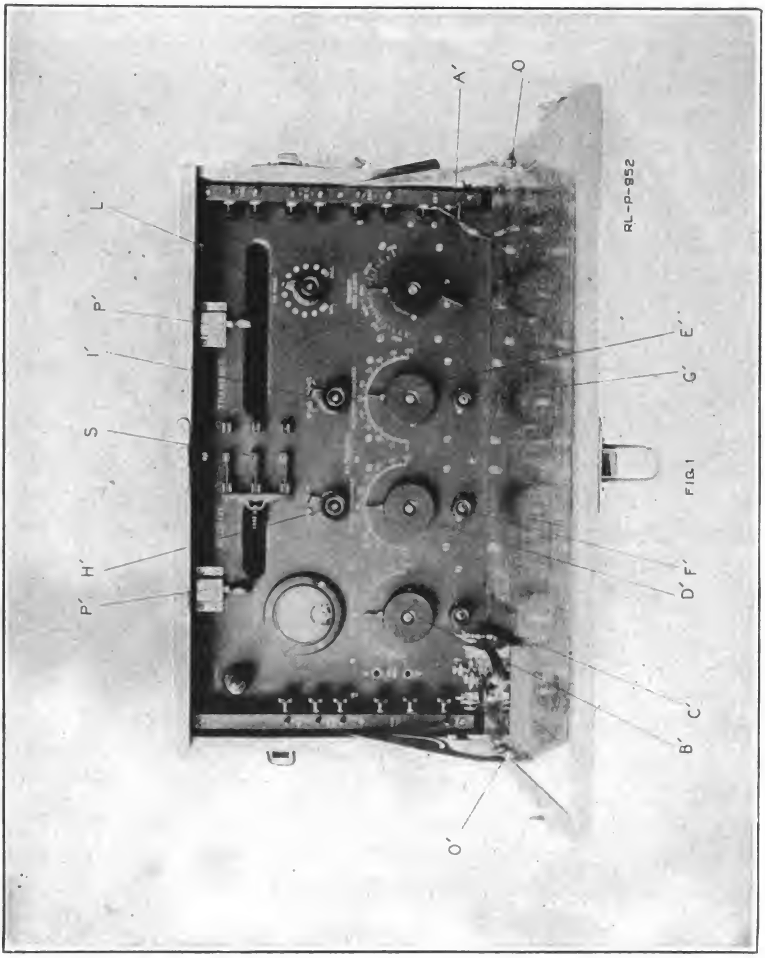
The wave-length variometer is located in the lower right-hand corner of the set box. It is equipped with a pointer and wave-length scale, which is direct reading. The scale is marked at intervals of 25 meters. There is a locking device shown at A′ (fig. 1) which can be used to lock the variometer at any desired setting.

The antenna-tuning variometer is located in the lower left-hand corner of the panel. It is shown at B′ (fig. 1) and its slow-motion knob at C′ (fig. 1). The slow-motion knob which moves the variometer by means of gears may be used for making fine tuning adjustments. This knob may be meshed with the gears at will by pushing it in toward the panel, and released by pulling it out. When the gears are meshed, there is sufficient friction so that the variometer is practically locked in position but may be moved easily by means of the small knob. The antenna variometer and wave-length variometers are located at opposite ends of the box in order to obtain minimum reaction between the two circuits, due to their mutual induction.

The Transmit-Receive switch is located in the center of the panel. It is thrown to the right to transmit, and to the left to receive. The filament circuits are open when the Transmit-Receive switch is open.

The receiving condensers are located in the central portion of the panel (D′ and E′, fig. 1). Both primary and secondary condensers are provided with slow-motion knobs (F′ and G′, fig. 1).

The antenna-coil switch (H′, fig. 1) for changing taps is located directly above the primary antenna circuit condenser. It is a two-position dial switch and the positions are marked "Short wave" and "Long wave." The coil has sufficient inductance when the switch


RL-P-952
FIG. 1

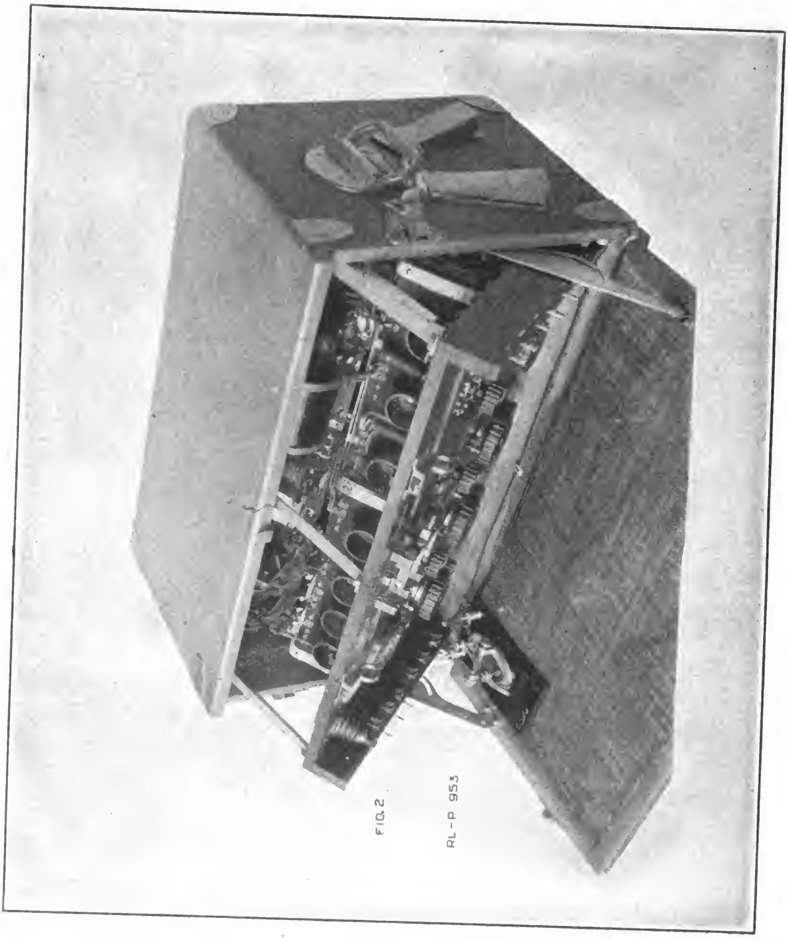


FIG. 2
RL-P 953

is in the long-wave position to tune to 1,100 meters on a smaller antenna than the one usually supplied.

The tickler-coil switch is located directly above the secondary condenser (I′, fig. 1). When the switch is in the position marked "SP," the tickler coil is shorted.

The receiving-tubes filament rheostat (L, fig. 1) is provided for compensating for the drop in the filament battery voltage as the batteries become exhausted. It is also useful in regulating the filament current of VT–5 tubes for the best reception. It is only in the circuit when a separate receiving filament battery is used.

The connections to the power equipment for the transmitter are all arranged in a vertical row at the right-hand end of the set box. The two-bottom binding posts marked "Key" are to be connected across the leads of the key. Both pins for plug connectors and binding posts for wire connections are provided for making connections from the set box to either the hand generator and battery box or to a storage battery and dynamotor. The plugs and cords for connecting to the hand generator and battery box or to a storage battery and dynamotor are supplied with the set. The low-voltage side of the hand generator is connected to the 12-volt terminals and the high-voltage side to the 350-volt terminals. When a storage battery and dynamotor are used, the 12-volt battery is connected to the 12-volt terminals and the motor side of the dynamotor to the dynamotor terminals. The generator side is connected to the 350-volt terminals. One blade of the Transmit-Receive switch is arranged to close the battery circuit to the dynamotor when the switch is in the transmitting position.

The power supply for the receiver is connected to the binding posts on the left-hand end of the set box when VT–5 tubes are used. The + fil. battery and —40 volts are common. Cords with plugs are provided for making the connections from the battery box to the set box.

The panel may be pulled forward at the top, as shown in figure 2, for placing tubes in the sockets and manipulating the switches S_3 and S_6 (fig. 8). The panel is held in place by catches at the top of the panel.

All of the apparatus inside the set box is mounted on the panel or on an aluminum frame which is attached to the panel. The entire set may be removed from the box. In order to remove the set from the box the two brackets which support the shelf must be removed from the shelf and the shelf dropped down until the lower edge of the panel will clear the key. To remove the set, first disconnect the leads to the key, then pull the top of the panel forward as shown in figure 2, raise the panel up about one-fourth inch, and pull the entire panel forward.

Power equipment.

The SCR–127 set uses a special hand generator as the source of power for the transmitter and three No. 6 dry cells in series for lighting the filaments of VT–5 tubes in the receiver. The SCR–130 set uses storage battery for lighting the filaments of both transmitting and receiving tubes and to drive a dynamotor for furnishing the plate current to the transmitting tubes. Dry batteries, type BA–8, are used for the 40–volt plate battery on the receiver.

The VT–5 tubes draw about 0.25 of an ampere from the No. 6 dry cells and about 2 milliamperes from the plate battery. The VT–1 tubes (used in SCR–130 set) draw 1.1 amperes from the storage battery and about 2.5 milliamperes from the plate battery.

The filament current required for the four VT–2 tubes in the transmitter is approximately 5.5 amperes. The plate current required by the transmitting tubes is approximately 200 milliamperes at 350 volts.

Hand generator (set SCR–127 only).

The hand generator is a double commutator shunt-wound D. C. generator, which generates 8 volts on the low-voltage side and 350 volts on the high-voltage side when the load is on. The armature is driven through a gear system by two handles, which should be turned at a rate of approximately 35 revolutions per minute. The direction of rotation of the handles must be as shown by the arrow on the top of the gear case.

The voltage is kept constant by means of a vibrating regulator which is mounted under the metal cover on the side of the generator. The regulator will maintain a constant voltage when the handles are turned at any speed between 35 and 60 revolutions per minute. No speed indicator is necessary, because the generator speed can vary through such wide limits without affecting the voltage. The regulator is set for the proper voltage and should not be changed.

The gearing is a combination planetary worm and spur type of high efficiency when in proper alignment. The high-speed shafts have ball bearings and the gears run in grease or oil, so as to reduce the friction as much as possible. The gears should never be taken apart unless absolutely necessary to replace worn or broken parts and then only by an experienced person. The gears and ball bearings must be lubricated by a nonfluid oil, which must be free from acid or water to prevent rusting.

The canvas cover supplied with the generator should be kept on at all times when the generator is not in use.

Dynamotor (set SCR–130 only).

The dynamotor, type DM–1, is a machine which changes a low-voltage direct current to a direct current at high voltage. The low-

voltage current is supplied by a 12-volt storage battery. The machine transforms this into a direct current having 350 volts. This type dynamotor is manufactured by Westinghouse. Its normal rate of rotation is 2,550 revolutions per minute. It supplies the power to the transmitting tubes of the set.

SETTING UP AND OPERATION OF SETS.

Setting up antenna.

At least five men are needed to erect the antenna. Three men are at the end of the antenna wires and guy ropes, two men raising the mast and adding the sections. The following directions should be observed:

Select clear space in which the antenna is to be erected. This clear space should be at least 225 feet in diameter. Unpack mast and antenna equipment and place in center of the space where the mast is to be erected. Take the top section (the one which has no iron pipe projecting from either end) and place the mast cap in one end of it. (The mast cap has eight sockets, which will hold the metal balls on the end of the antenna wires. It should have the antenna lead-in wire permanently fastened to it.) Attach the six antenna wires to the mast cap by means of the ball and sockets provided. Unreel and lay out on the ground the six antenna wires and the guy ropes fastened to them. The antenna wires are the smaller sized wires. They extend out radially from the mast. They should divide the circle in equal parts—that is, they should make angles of 60° with each other.

Place a man at every other guy rope, at the end of the guy rope. It is the duty of these three men to keep the mast upright as the sections are added. They do this by keeping the correct strain on the guy ropes, walking toward the mast as necessary. Select the eight other sections to be added (all alike) and the bottom section. (This has an insulator screwed on the bottom of it. If it is not screwed on, this should be done before adding the sections to the mast.) The mast will contain, when erected, 10 sections in all, 8 besides the top and bottom sections.

Add the sections, one man raising the mast directly upward and the other man adding the sections. Keep the mast upright, giving any directions that may be necessary to the men at the end of the guy ropes to do this. Having added all the sections, including the bottom one, allow the mast to rest on the ground. The two men at the mast then go out to the end of a guy rope and drive a stake in the ground and by means of the metal tent slide tighten the guy to the proper tension. This is done for each of the six guy ropes. Be careful that the mast is upright and that it is not bent. Make any changes in the strain on the guys necessary to do this.

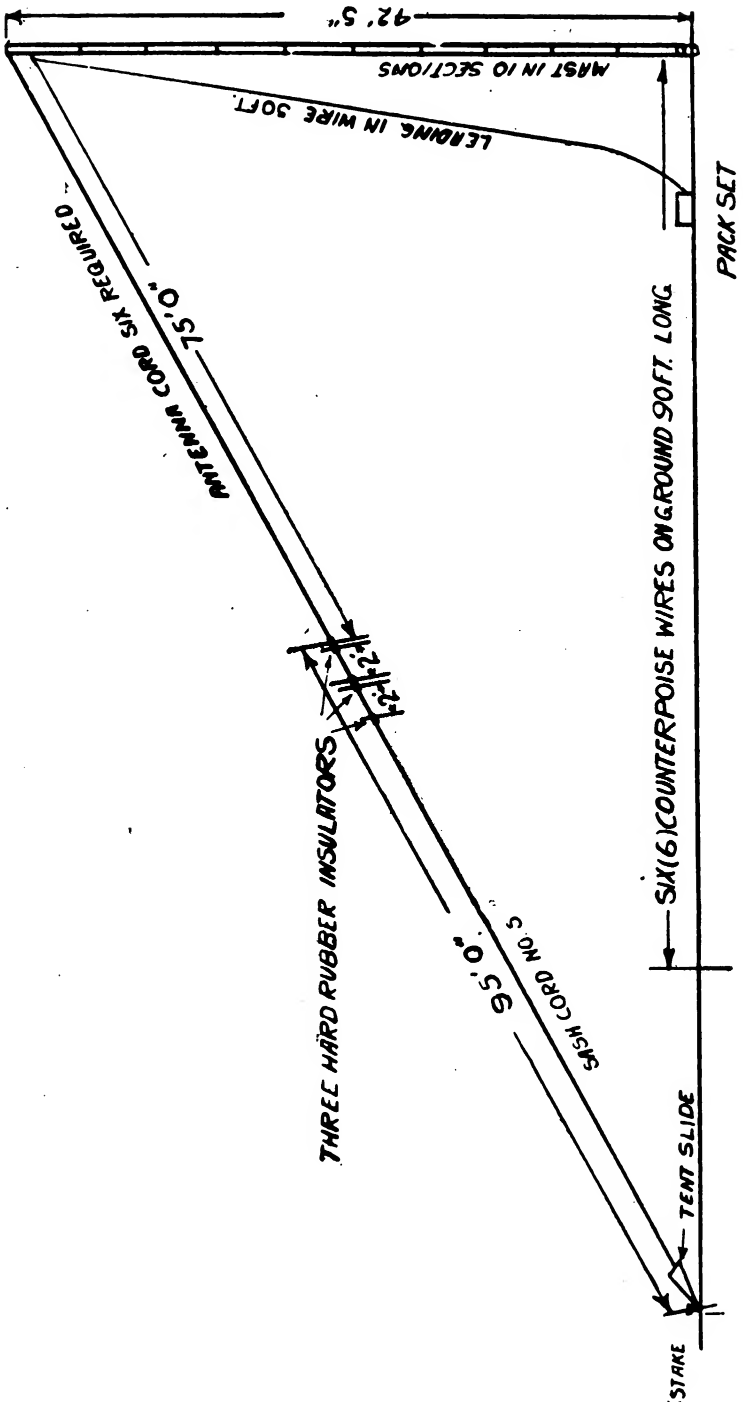
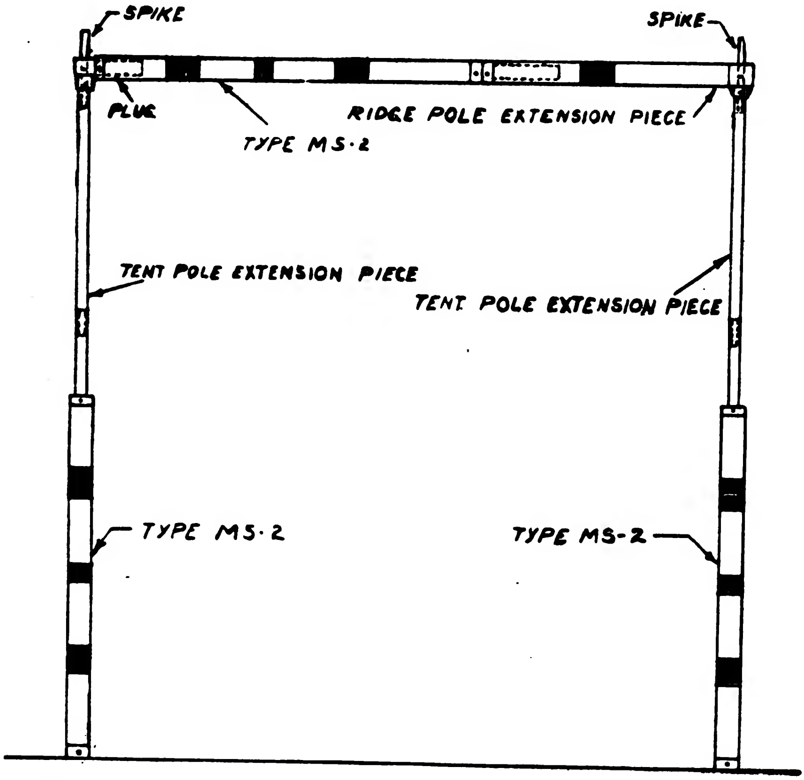


FIG. 3

RL-P 1416

It is to be noted that on each guy rope there is an insulator between it and the antenna wire to which it is fastened. The rope is also divided by insulators. It is absolutely necessary that the antenna wires be well insulated. The antenna wires must not touch an object such as a tree, building, etc. The lead-in wire hangs down beside the mast.

Having erected the antenna, place the counterpoise connecting block on the ground near the mast. (This is fitted with holes in which the ends of the counterpoise wire are plugged.) A short wire



BL—P—1417 FIG. 3A.

leading to the set box is attached to it. Reel out the six counterpoise wires to their full extent. They rest on the ground, each directly under an antenna wire. No further insulation is necessary in addition to the insulation on the wire itself. The counterpoise connecting block should be raised off the ground, if necessary, to properly insulate it. Figure 3 shows the antenna properly erected.

Battery box.

The battery box (shown in fig. 4) is divided into 8 compartments, 4 in the front and 4 in the back of the box. The square compartment

on the left front contains the terminals for the battery connections. The compartments in the front, covered by a black lid, hold the BA–8 (square) batteries. To connect these batteries observe the following rules: Having removed the lid, take a BA–8 battery and cut off the middle (green) wire as close to battery as possible. Put the battery in the front compartment, sealing wax side to front, and *red* terminal wire *up*. Slip the black terminal wire through the small hole in the end of the compartment near the bottom. Fasten the black terminal wire to the clip or binding post marked "Black (—)." Fasten the red terminal wire to the clip marked "40 V. Red (+)."

Take a second BA–8 battery and having cut off the *green wire* place it in the other compartment alongside the first battery. Put it in with the sealing wax side to the rear and the *black* terminal up. Slip the red terminal wire through the small hole in the end of the compartment near the bottom. Fasten it to clip on binding post marked "Red (+)." Fasten the black terminal wire to the clip marked "40 V. Black (—)."

Place the two spare batteries in the compartment alongside the two batteries in use. Be careful that the wires of the spare batteries do not touch each other. Place the black lid over the compartment.

Dry batteries No. 6 (SCR–127 set only).

These batteries are used only in the SCR–127 set. They belong in the two long compartments in the rear of the box. Only three are in use, the others are spare. To connect these batteries, connect the center terminal of one to the outer terminal of the second and the center terminal of the second to the outer terminal of the third. Now connect a short wire leading from the binding post marked "Zinc (—)" to the outer terminal of the first battery. Connect a wire leading from the binding post marked "Carbon (+)" to the center terminal of the third battery. Place the spare batteries in the compartment alongside those in use. Clamp all the batteries down by means of the sticks provided.

Generator (set SCR–127 only).

Mount the generator on the stand provided and attach the handles. The handles are placed to extend in a straight line one opposite to the other. The machine is turned by two men. The speed should be greater than 35 revolutions per minute and not greater than 60 per minute.

Set box.

Place set box on legs provided for it. Open the front of the box by pulling out after releasing the catches on both sides and top. *Pull the Receiver-Transmit switch directly outward so that it makes*

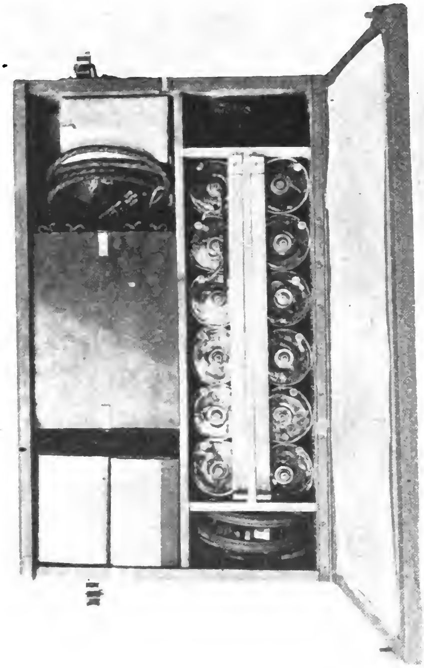


FIG. 4

RL-P-955

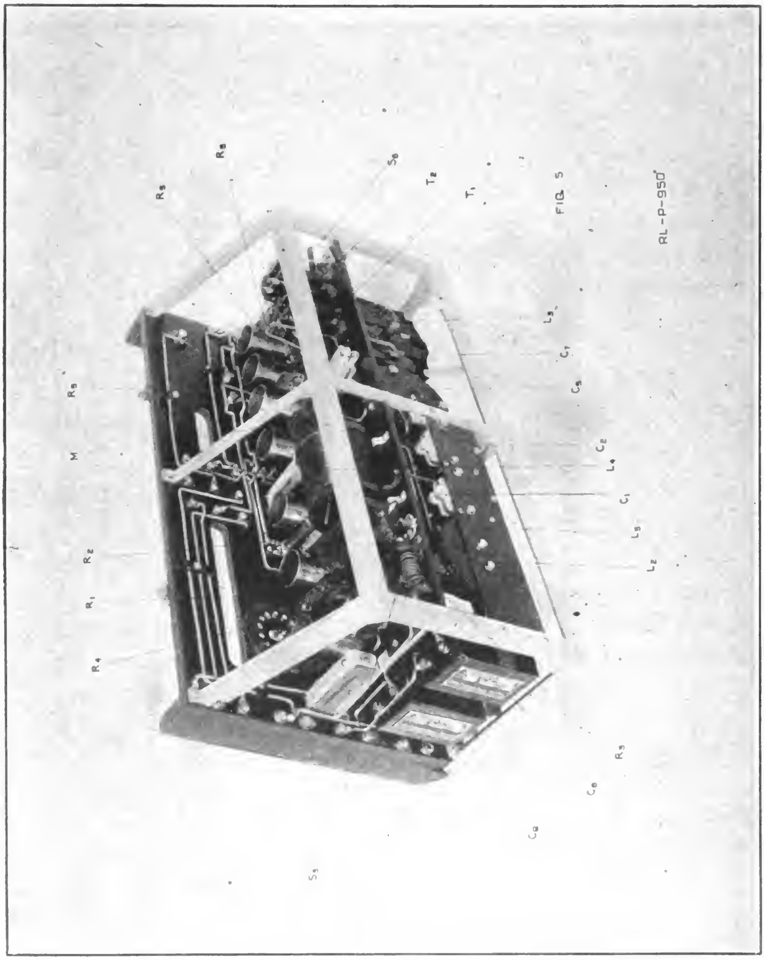


FIG. 5

neither contact. The panel of the set tilts forward by pulling down and outward two catches mounted on the panel. Tilt it forward and place in each of the four sockets to the right a VT–2 tube. Place in each of the three sockets to the left a VT–5 or VT–3 tube for the SCR–127 set, and a VT–1 tube for the SCR–130 set. Close the panel. Connect the two leads of the key to the two lower right-hand terminals marked "Key." Connect the antenna lead-in wire to the upper left terminal marked "Antenna." Connect the lead-in wire from the counterpoise to the lower left terminal marked "GND." Take care to see that the lead-in wire is not wrapped around or touching the mast or the set box. It may be necessary to move the set box slightly to insure this condition.

Other connection for SCR–127 set.

On the right-hand side of the set box are pairs of plugs marked "Dyn.," "12 V.," and "350 V." The Dyn. plugs are not to be used. Take the connecting cord marked "350 V." and connect the one end to the 350 V. terminals on the set box and the other end to the plug on hand generator marked "350 V." Take the connecting cord marked "8 V." on one end and "12 V." on the other end and connect the end marked "12 V." to the 12 V. plugs on set. Connect the 8 V. end to the 8 V. plug on the opposite side of generator.

On the left side of the set box are three plugs marked "40 V. and Fil. Bat." Take the connecting cord marked "40 V. Plate Bat. and Fil. Bat." and connect it to the plugs. Connect the wire from the + 40 V. plug to the unused part of the binding post in the battery box marked "+ 40 V. Red." Connect the wire from the common middle plug of the connecting cord to the unused part of the binding post marked "— 40 V. Black." Take the wire connected to the — Fil. Bat. plug and connect it to the unused part of the binding post marked "Zinc —." The "carbon" binding post and the "— 40 V. Black" binding post in the battery box must be connected by a short length of wire.

Plug in your phones in either of the holes marked "Tel. Rec." Again tilt the panel forward and *close* the small knife switch (fig. 5, S_3) at the rear right-hand corner and throw the double-throw switch (fig. 5, S_6), mounted in the corresponding position on the left, *away* from the operator. (These need never again be changed while using the set as described.) Close the panel and the set is connected ready for operation when the Receive-Transmit switch is thrown to the proper side.

Other connections for SCR–130 set.

On the left-hand side of the set box are three pairs of plugs marked "Dyn.," "12 V.," and "350 V." Take the connecting cord marked "350 V." on one end and having tinned copper terminals on the

other end and connect one end to the set box plugs marked "350 V." Connect the tinned copper terminals to the 350-volt (generator) side of the dynamotor. Be sure to connect the positive (+) and negative (—) wires to the correct terminals.

Take the wire marked "Dyn." on one end and having tinned copper terminals on the other and connect one end to the set box plugs marked "Dyn." and connect the other end to the 12-volt (motor) side of the dynamotor. Be sure to connect the positive (+) and negative (—) wires to the correct terminals.

Connect three 4-volt batteries (type BB–14, lead) in series by means of the cords provided. Take the connector cord marked "12 V." on one end and having lead covered copper lugs on the other end, connect one end to the set box plugs marked "12 V." and the lugs to the terminals of the storage batteries.

On the left side of the set box are three plugs marked "40 V." and "Fil. Bat." Take the connecting cord marked "40 V. Plate Bat. and Fil. Bat." and connect it to the plugs. Connect the wire from the + 40 V. plug to the unused part of the binding post in the battery box marked "+ 40 V. Red." Connect the wire from the common middle plug of the connecting cord to the unused part of the binding post marked "— 40 V Black." The other wire is not used, because power for the receiving tube filaments is obtained from the storage battery. Wrap the end with tape so that it will not short circuit or come in contact with the other leads.

Plug in your phones in either of the holes marked "Tel. Rec." Again tilt the panel forward and *open* the small knife switch (fig. 5 S_3) at the rear right-hand corner and throw the double-throw switch (fig. 5 S_6), mounted in the corresponding portion on the left, *toward* the operator. (These need never again be changed while using the set as described.) Close the panel and the set is connected ready for operation when the Receive-Transmit switch is thrown to the proper side.

OPERATING INSTRUCTIONS.

The antenna tuning, the primary condenser, and the secondary condenser are variable. They should be varied when necessary by turning the small knob placed immediately beneath the larger knob. Do not attempt to vary them by turning the large knobs without first pulling outward the small knob below. The Transmit Wave Length is also variable. Throw the locking lever below it to the right before attempting to move it. When on the desired wave length, it is locked by throwing the locking lever to the left.

To transmit.

Set the Transmit Wave Length pointer to the desired wave length and lock it there by throwing the lever beneath it.

Turn the hand generator (SCR–127 set) at a speed of 35 to 60 revolutions per minute. (On the SCR–130 set the dynamotor will start when the switch is thrown.) Throw the Transmit-Receive switch to its transmitting position and note if the four tubes on the right are lighted. Close the key and turn the Antenna Tuning knob back and forth slowly until the greatest reading is obtained on the ammeter mounted on the set marked "Antenna Current." This reading should be greater than 0.7 ampere. It is to be noted that in transmitting, only the Transmit Wave Length and Antenna Tuning knobs are used.

To receive.

Turn the Fil. Rheo. knob all the way over to the left (Min.). Throw the Transmit-Receive switch to the receiving position and turn the Fil. Rheo. knob until the filaments of the three tubes to the left become cherry red. Place telephone receivers on head and test the tubes by throwing the SP–Het. knob from one side to the other. If the tubes are working all right a click should be heard in the receiver. If no click is heard, turn the Fil. Rheo. knob farther to the right and work the SP–Het. knob. Do this until a click is heard in the receiver. This shows that your set is oscillating properly. (Note: Filament rheostat is in circuit in SCR–127 set only.)

If receiving from a similar set, or any undamped wave set, turn the SP–Het. knob to the Het. side and leave it there. If it is desired to receive from station using spark (damped wave), the switch is thrown to the SP side.

If it is desired to receive wave lengths of from 350 to 550 meters, the S. W.–L. W. switch should be placed on S. W. (short waves). To receive wave lengths of from 500 to 1,100 meters, put the S. W.-L. W. switch on the L. W. side.

To tune, vary the primary condenser and the secondary condenser until the signals are heard on the telephone. Turn the knobs *slowly*. Only experience can teach how to get a desired signal. If no results are obtained after trying several minutes, it may be necessary to search the field. To do this, set the primary condenser at 0 and slowly move the secondary condenser through its whole range. Then move the primary condenser to 5 and slowly move the secondary condenser through its whole range. Repeat this until the desired signals are heard.

Hints and suggestions.

If the set fails to work, carefully examine all connections which *you* have made.

Interchange the receiving tubes until you have found the combination that works best. Some work better in one socket than in another. That is, some tubes are better detectors than others. One of the tubes is connected as a detector.

Do not try to take the set apart in any way or attempt to change any of the connections.

In transmitting, if any of the four tubes fail to light it may be due to a bad connection in the socket or a dirty contact pin. Clean the contact pin and replace the tube properly in the socket. If this does not remedy the defect, try a new tube. In exchanging tubes *always* pull the Transmit-Receive switch so that it makes no contact.

In receiving, all three of the tubes will light or none of them will, because their filaments are connected in series. If they fail to light, it is due to a bad tube or poor connection. Examine and clean your connection. If necessary, find by trial the defective tube and replace it.

The instruction contained in figure 6 for the care of the P–11 head set should be carefully observed.

When the SCR–130 set is first installed and no radiation can be secured after the proper connections have been made, the fault may be due to the reversal of the dynamotor polarity. To remedy this, reverse the leads from the dynamotor to the operating chest (set box), i. e., attach + lead to — terminal and — lead to + terminal.

(SCR–127 SET ONLY.)

If none of the transmitting tubes light, then the generator either does not build up or the circuit is open. Test the generator voltage. If the generator does not build up, remove the cover from the regulator and clean the contact on the vibrator carefully with a piece of sandpaper. If the generator still does not build up, connect the dry cells which are used for the receiving tube filament battery to the low-voltage terminals of the generator for an instant. Do not leave the cells connected. It only requires an instant to magnetize the field of the generator so that it will build up. If the trouble is not in the generator, test the voltage on the 12-volt binding posts on the set box. If the voltage is there, then clean the blades of the Transmit-Receive switch. If the tubes still do not light, remove the set from the box and examine the filament circuit for a broken connection.

CARE OF HAND GENERATOR (SCR–127 SET).

The large gear case is packed with grease which should never require renewal during the life of the machine. However, a hole is provided on one side near the top. The old grease can be washed out with gasoline and new grease supplied through this hole. About 1½ pints of grease are required.

At one end of the machine is a gear casing containing two gears, the smaller of which is on the armature shaft. These gears need only

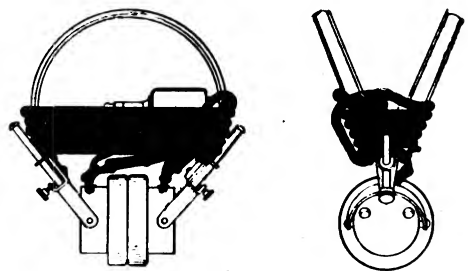
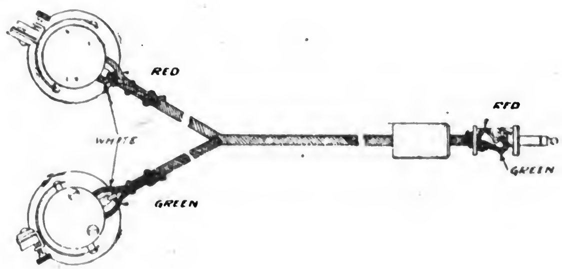


FIG 2



NOTES

AFTER THE TYPE P-11 RECEIVER IS ASSEMBLED, THE POLES OF THE PERMANENT MAGNETS ARE GROUND IN ORDER TO OBTAIN THE PROPER CLEARANCE UNDER THE DIAPHRAGM THIS GRINDING IS REQUIRED BECAUSE THE STANDARD PARTS USED CANNOT OTHERWISE BE ASSEMBLED WITH SUFFICIENT ACCURACY. IT IS EXTREMELY IMPORTANT THAT THE RECEIVERS SHOULD <u>NEVER</u> BE TAKEN APART

IF IT BECOMES NECESSARY TO REMOVE THE CORD CONNECTIONS FROM EITHER THE TELEPHONES OR THE PLUG, THE WIRES <u>MUST</u> BE REPLACED ACCORDING TO THE COLOR SCHEME SHOWN IN FIG. 1. ALL THE TELEPHONE JACKS ARE CONNECTED WITH THE SPRING POSITIVE WITH RESPECT TO THE SLEEVE, SO THAT WHENEVER THERE IS A CONTINUOUS CURRENT FLOWING THRU THE RECEIVERS, ITS DIRECTION IS SUCH THAT THE FLUX SET UP WILL BE IN THE SAME DIRECTION AS THE FLUX FROM THE PERMANENT MAGNETS. IF THE CORDS ARE REMOVED AND REPLACED IN THE WRONG DIRECTION, THE PERMANENT MAGNETS WILL BE PARTIALLY DEMAGNETIZED, AND THE EFFICIENCY OF THE TELEPHONE RECEIVERS SERIOUSLY IMPAIRED

FIGURE 2 SHOWS THE STANDARD PRACTISE OF WRAPPING TELEPHONE RECEIVERS TO FIT CARRYING COMPARTMENTS. THIS METHOD IS CHOSEN BECAUSE IT PROTECTS BOTH DIAPHRAGMS AND TERMINALS. THIS METHOD SHOULD ALWAYS BE USED WHEN PUTTING AWAY TELEPHONE HEAD SETS.

RL-P-956

FIG. 6

a small amount of grease for lubrication. The ball bearing for the large upper gear and the bearing at each end of the armature is packed in grease, which only need be renewed at long intervals. Access to the bearings can only be obtained by disassembling the lower part of the machine.

The first experimental models of the generator provide no means of access to the brushes and commutators, so the lower part of the machine must be taken apart to get at them. The improved machines to be manufactured in quantity provide plates on the sides of the machines to facilitate getting at the brushes and commutators.

The lower part of the machine can be taken apart most easily by following the directions given below.

(*a*) Unscrew cover of side gear casing, which is fastened by 14 screws.

(*b*) Holding the flywheel stationary, unscrew the nut securing the large upper gear. Draw off this gear and unscrew the large clamping nut under it.

(*c*) Still holding the flywheel stationary, unscrew the nut securing the small lower gear. Draw off this gear and unscrew the large clamping nut under it. The inner half of the gear casing can now be removed.

(*d*) Still holding the flywheel stationary, unscrew the nut securing the flywheel. Then draw off the flywheel.

(*e*) The end plates are removed by unscrewing three screws and then prying off the plates. The armature bearings are in the end plates, so the armature will rest on its field pole pieces when the end plates are removed.

(*f*) If the generator is one of the improved type, the armature can now be withdrawn.

(*g*) If the generator is one of the first experimental models, the entire generator must be withdrawn from the casing. The single screw securing the connection-plug receptacle on each side is removed, the receptacles pulled out and disconnected, and the leads pushed back inside the casing. Three screws on each side of the casing and one on the bottom of the casing are removed. The entire generator can now be drawn out, allowing access to the brushes and commutators. The two long bolts extending through the machine are removed to allow removal of generator end plate if necessary to take out armature.

The generator is reassembled by following the above directions in the reverse order. Great care should be taken that all parts go together in exactly the same relative positions as they were originally.

CARE OF DYNAMOTOR (SCR-130 SET).

The bakelite panel in the dynamotor-carrying box should be kept clean.

Two oil holes are provided on the panel, through which the bearings are lubricated. A light machine oil should be supplied at the rate of a few drops for each hour of continuous operation.

A 20-ampere fuse is connected in the motor circuit. The fuse will blow for any undue load on the generator.

A D. P. S. T. switch affords a convenient method of opening the high-voltage circuit if for any reason it is desired to cut this voltage off from the set box panel.

If the generator fails to build up, it is probably due to a dirty commutator. The commutators of both the motor and generator should be kept clean and smooth by applying fine sandpaper and a piece of absorbent cloth. The commutators require no lubricant.

PRINCIPLES EMBODIED IN THE SETS.

Transmitter.

The transmitter is of the vacuum-tube type, Signal Corps VT-2 tubes being used. One tube is employed as an oscillator and three tubes in parallel are used to amplify the power from the oscillating tube. The characteristics of the power amplifier type of vacuum-tube transmitters are such that this type of circuit is particularly well suited for portable field sets. The adjustments are a minimum, and as the wave length of the oscillating circuit is varied by a single variable inductance, the other constants of the oscillating circuit are fixed, the variable inductance is provided with a pointer and scale reading directly in wave lengths. No wave meter is needed with this set. The antenna is not connected directly in the oscillating circuit or to it, but is connected to the plate circuit of the amplifying tubes by means of a transformer. The grids of the amplifying tubes are connected in parallel and are connected across one of the condensers in the oscillating circuit. The voltage across this condenser is impressed upon the grids of the amplifier tubes, thereby developing a voltage in the plate circuit which causes an alternating current of the same frequency to flow in the plate circuits of the amplifying tubes. The three tubes in parallel permit three times as large a current to flow through the primary of the transformer as could be obtained with one tube. The power supplied to the antenna is also three times as much, in this case, as would be supplied by one tube. The transformer is adjusted so that the effective antenna resistance as reflected in the common plate circuit of the tubes is such as to develop the maximum power output of the tubes. This output is limited by the heat developed at the plates of the tubes. The antenna is tuned with the oscillating plate circuit by means of a single variometer. The antenna circuit does not affect the wave length. The maximum deflection of the pointer on the ammeter is obtained when the antenna is tuned to the wave length of the current in the oscillating circuit.

A simplified diagram is shown in figure 7A; the complete circuit diagram being shown in figure 7. The oscillating circuit which acts as an exciter for the grids of the power amplifier tubes may be considered as an alternating-current generator. The frequency of the alternating current generated is determined by the constants of the oscillating circuit, in the same way as the frequency of an alter-

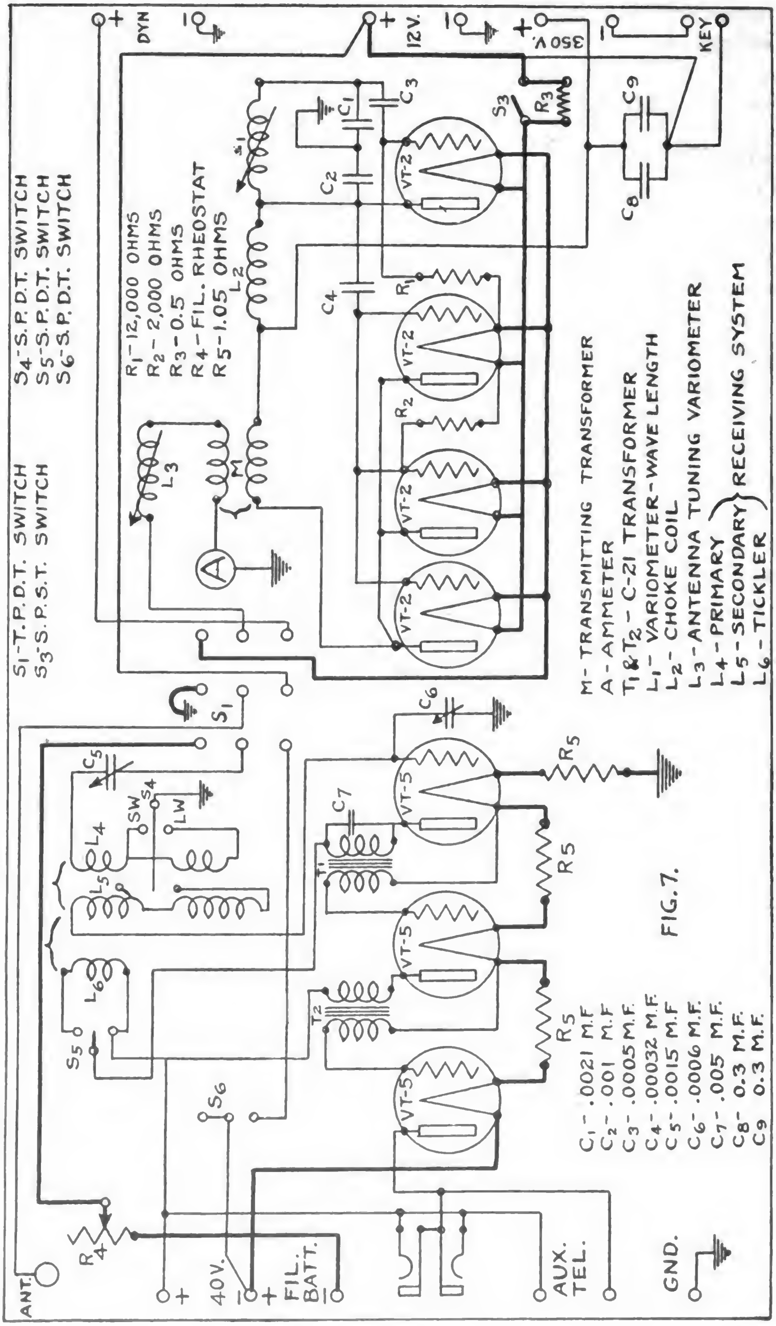

S1-T.P.D.T. SWITCH
S3-S.P.S.T. SWITCH
S4-S.P.D.T. SWITCH
S5-S.P.D.T. SWITCH
S6-S.P.D.T. SWITCH
R1-12,000 OHMS
R2-2,000 OHMS
R3-0.5 OHMS
R4-FIL. RHEOSTAT
R5-1.05 OHMS
M-TRANSMITTING TRANSFORMER
A-AMMETER
T1 & T2-C-21 TRANSFORMER
L1-VARIOMETER-WAVE LENGTH
L2-CHOKE COIL
L3-ANTENNA TUNING VARIOMETER
L4-PRIMARY
L5-SECONDARY
L6-TICKLER
RECEIVING SYSTEM
C1-.0021 M.F.
C2-.001 M.F.
C3-.0005 M.F.
C4-.00032 M.F.
C5-.0015 M.F.
C6-.0006 M.F.
C7-.005 M.F.
C8-0.3 M.F.
C9 0.3 M.F.
DYN
12V.
350 V.
KEY
ANT.
40V.
FIL. BATT.
AUX. TEL.
GND.
VT-2
VT-5

FIG. 7.

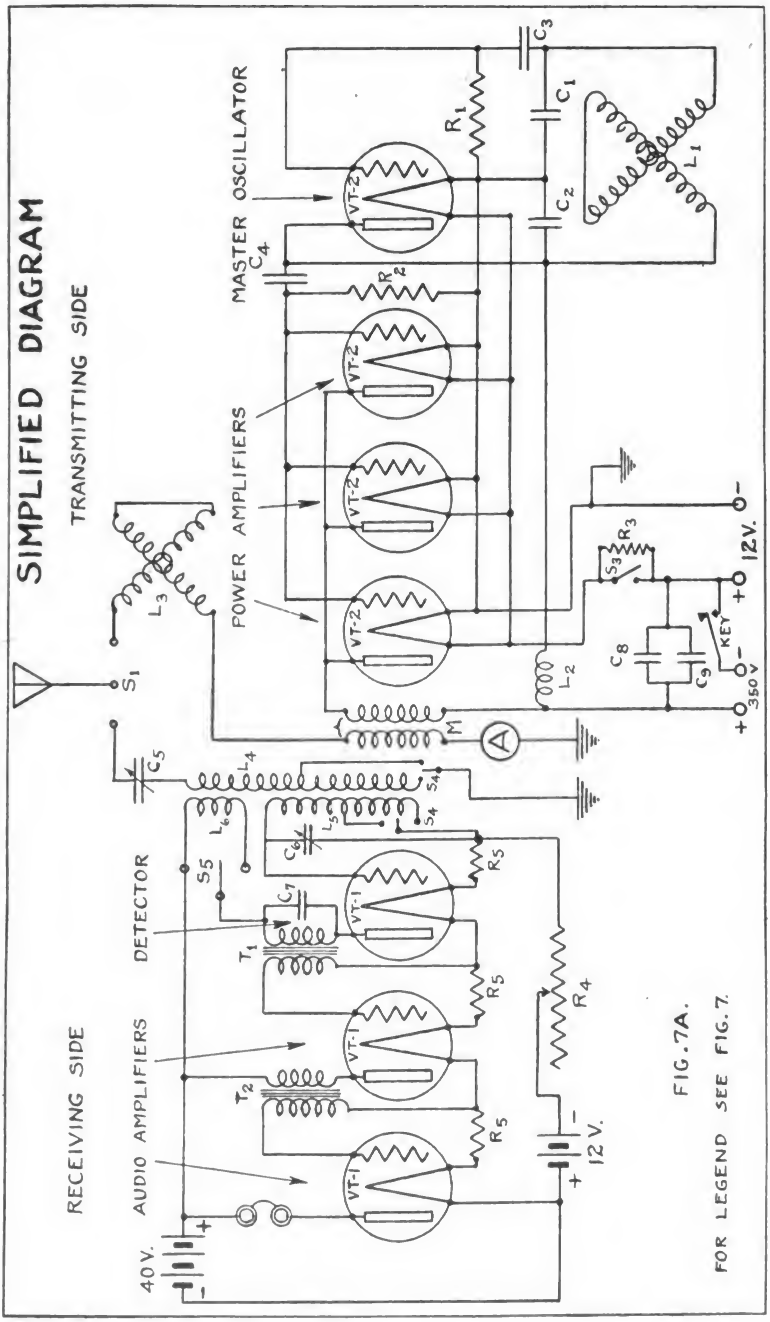


FIG. 7A.

FOR LEGEND SEE FIG. 7.

nator is determined by the number of poles and revolutions per minute of the rotor. The frequency of wave length is determined by the values of the inductance L_1 and the condensers C_1 and C_2 which are in series. The frequency is, approximately:

$$f = 2\pi \frac{1}{\sqrt{L\frac{C_1C_2}{C_1+C_2}}}$$

The power necessary to maintain the oscillations in this circuit is furnished by one VT–2 tube. The condenser C_1 is connected between the grid and filament of the tube so that the voltage across the condenser is applied between the grid and filament. This voltage, because of the amplifying power of the tube, causes a greater voltage to act in phase with it across the condenser C_2 than is developed across this condenser by the oscillating current. The oscillating current reaches a value such that the losses due to the resistance of the circuit equal the power supplied by the tube. The power supplied by the oscillating tube to the circuit at high frequency is supplied to the plate circuit of the tube as direct current. The direct current flows from plate to filament and the variations of grid voltage cause variations in the resistance offered by the plate-filament circuit to the flow of this current. The choke coil L_2 maintains this current at a constant value; therefore the variations in the plate current flow through the condenser C_2. The voltage developed across C_2 then acts on the oscillating circuit to cause a current to flow, which is in proper phase to cause a further variation in the voltage applied between the grid and filament. The condenser C_3 serves to prevent the direct-current voltage supplied to the plate from reaching the grid. Since the alternating current passes through the condenser C_3, and since the grid-filament circuit of the tube conducts current in one direction only, a charge will accumulate on the condenser C_3. If no means were provided to rid the condenser of this charge it would soon reach a value which would cause the grid to have such a large negative voltage with respect to the filament that the plate current would be blocked and the tube would cease to operate. The resistance R_1 is provided to take care of this charge and allows it to leak off at a rate which maintains a steady negative voltage on the grid of the proper value to insure efficient operation of the tube. The values of the capacities, inductances, and resistance are shown in figure 7. The variometer L_1 is used to change the wave length of the oscillating current. This variometer has an inductance range of 0.5 m. h. to 0.12 m. h. C_1, C_2, and C_3 are small mica condensers. C_3 is inside the bakelite panel and can not be seen in the picture (fig. 5).

The three VT–2 tubes have their grids connected together and the plates connected together. The filaments are also connected to a common lead which connects to the filament of the oscillator tube.

The alternating current in the plate circuit of the amplifier tubes induces a current in the antenna circuit through the transformer M. The transformer is not tuned on the primary side. There is no variable coupling between the plate circuit of the amplifier and the antenna. The coupling is made as close as possible. The primary of the transformer has a high inductance, so that it acts as a choke coil to limit the plate current of the amplifier tubes when the antenna is detuned. The ratio of the primary turns to secondary turns is determined by the ratio of the antenna resistance to the internal impedance of the tube; this ratio is made suitable for the antenna which is supplied with the set. The grids of the amplifier tubes are connected through the condenser C_4 to the plate of the oscillator tube. Since the filaments of the amplifiers and oscillator are connected to a common lead, the alternating voltage across the condenser C_2 is applied through the condenser C_4 to the grids of the amplifier tubes. C_4 serves to prevent the direct-current voltage to the plate of the oscillator tube from reaching the grids of the amplifier tubes. The grid-filament circuit of the amplifier tubes permits current to flow only on the half of the cycle which makes the grids positive with respect to the filaments, and therefore the condenser C_4 becomes charged so that the grids become negative with respect to the filaments. The resistance R_2 has the correct value to keep the negative potential on the grids at a value which causes the tubes to operate on the part of their characteristic curves where the tubes operate efficiently as amplifiers.

The antenna circuit includes the secondary of the transformer, variometer for tuning, and the radiofrequency ammeter. The variometer L_3 is shown in figures 5 and 8. The inductance range of the variometer is sufficient to take care of variations in the capacity of the antenna which may occur due to soil conditions, etc.

Receiver.

The receiver consists of antenna circuit, tuned secondary circuit, vacuum-tube detector, and two-stage audiofrequency amplifier. A fixed tickler coupling with a short-circuiting switch provides for the reception of either damped or undamped signals. The receiver is designed primarily for the reception of undamped waves, and is designed so that the minimum number of adjustments is necessary for its operation.

The antenna circuit consists of a coil having one tap and a continuously variable air condenser connected in series between the antenna and ground connections. The coil L_4 and the condenser C_5 are shown in figures 5 and 8. The antenna inductance switch is shown at S_4.

The secondary circuit consists of a a coil L_5 and a continuously variable air condenser C_6, connected in parallel between the grid and filament of the detector tube.

Magnetic coupling between the antenna and secondary circuits is obtained by the mutual inductance between the entire secondary and primary coils. The coils are arranged so that the proper degree of coupling may be obtained by rotating the secondary coil longitudinally about the center of its axis. The motion is limited, but is ample for the necessary adjustment. The coupling is carefully adjusted for the best reception on undamped waves over the entire range of wave lengths and fixed so that it can not be changed from the panel. The coupling is not the most efficient for damped waves when adjusted for undamped wave reception, but it is not made variable because the set will be most frequently used on undamped waves and, as stated above, it is desired to make the operation as simple as possible.

The detector tube is made to oscillate by means of a coil L_6 which is connected in its plate circuit and inductively coupled to the secondary receiving coil. The inductive feed back is not variable, but is designed so that the feed back is sufficient to keep a VT–1 or VT–5 tube oscillating. The tickler coil is located inside of the secondary coil. The tickler coil may be short circuited for damped wave reception by means of the switch S_5.

Two stages of audio frequency amplification are provided. The coupling between successive stages is obtained through iron-core transformers. The primary windings of the transformers are connected in series with the plate battery in the plate-filament circuits. The first transformer primary is connected in series with the tickler coil in the plate circuit of the detector tubes. There is a condenser C_7 which serves as a by-pass for the radiofrequency current. The secondaries of the transformers (T_1 and T_2) are connected between the grids and filaments of the amplifier tubes. The two telephone jacks (*j*) are in parallel in the plate circuit of the second amplifier tube. Auxiliary binding posts are connected across the jacks for using receivers without plugs.

Power circuits.

The filaments of the transmitting tubes are in parallel across the 12-volt binding posts. The negative side is closed by one blade of the Transmit-Receive switch S_1. The resistance of 0.5 ohm, R_3, must be shorted by the switch S_3 when using the hand generator, which supplies 8 volts. It must be open when using a 12-volt storage battery. The receiving-tube filaments are in series. Either VT–1 or VT–5 tubes may be used in this set. When the set box is to be used with the SCR–127 Cavalry pack set, VT–5 tubes are used and the filament current is supplied by three No. 6 dry cells in series.

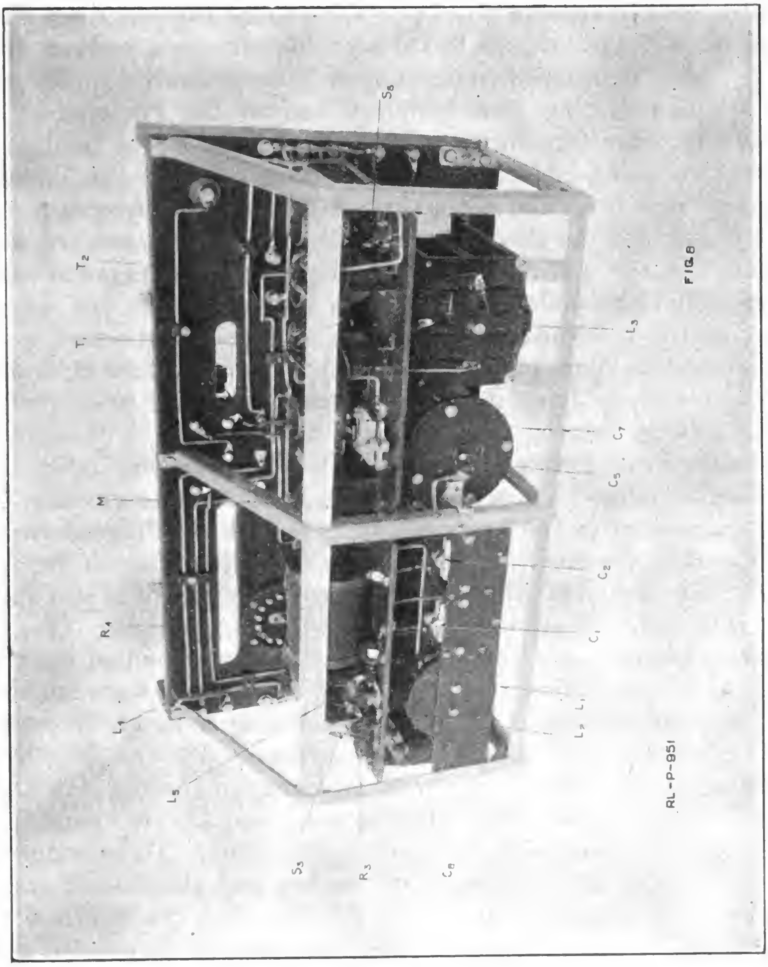


FIG. 8
RL-P-951

When VT–5 tubes are used the dry cells are connected to the binding posts on the left-hand end of the set box which are marked "+ and — filament battery." The switch S_6 must be thrown away from the panel and pressed firmly in the holding clips in order that it will be held in the open position. The filament rheostat R_4 is in series with the receiving-tube filaments when S_6 is in the open position, as it must be when VT–5 tubes are used. The filament circuit is closed by one blade of the Transmit-Receive switch when the switch is in the receive position. VT–1 tubes are used when the set box is used with the SCR–130 set. The filament current of the VT–1 tubes is supplied from the same battery which supplies power to the transmitting tube filaments and to the dynamotor. The switch S_6 when thrown toward the panel connects the positive end of the receiving-tube-filament circuit to a point on the Transmit-Receive switch so that when that switch is in the receive position the positive of the 12-volt transmitting battery is connected to the positive end of the receiving-tube filaments. The negative end of the receiving-tube-filament circuit is grounded, also the negative side of the transmitting battery. The filament rheostat in the receiving-tube-filament circuit is not in the circuit when S_6 is in the position for supplying the filament current to VT–1 tubes from the transmitting battery. The resistances R_5 serve to produce the necessary biasing voltages for the grids of the receiving tubes.

The Transmit-Receive switch serves to throw the antenna from the transmitter to the receiver, open and close the filament circuits, and to close the circuit from the 12-volt binding posts to the dynamotor binding posts. The secondary receiving circuit is also opened when the switch is thrown to the transmitting position. This is to prevent the receiving circuit from drawing energy out of the transmitting circuit if they should be tuned to the same wave length.

The plate circuits of the four transmitting tubes are in parallel. The plate voltage is applied between the — 350 and + 350 volt binding posts. The — 350 volts is connected through the key to the + 12-volt post. The condensers C_8 and C_9 are connected in parallel and across the key and + 350 volts. These condensers prevent arcing at the contacts of the key and also smooth out the commutator ripples in the plate voltage when the key is closed. The plate circuits of the receiving tubes are all in parallel across the + filament battery, — 40-volt binding post, and the + 40-volt binding post.

TRANSPORTATION SCR-127 SET.

The set is normally packed on three mules. The following is a packing list:

NO. 1 MULE.

1 generator, type GN-29.
2 cranks, type GC-1.
1 stand, type GS-1.
1 hood, type BG-9; for generator.
4 bolts, type M-2; for generator stand.
2 plates, type M-3; for generator stand.
6 mast sections, type MS-2.
1 frame, type M-1.
1 cincha band, type ST-7.
2 straps, type ST-8 (three straps connected to ring).
2 straps, with snap hooks at each end.

NO. 2 MULE.

1 set box BC-7, including following parts:
  4 tubes, type VT-2.
  3 tubes, type VT-5.
  3 adapters, type FT-65.
  1 instruction pamphlet.
4 legs for set box, type BC-7.
1 box, type BC-102, including following parts:
  1 cord, type CD-87; 350-volt leads, generator to set box.
  1 cord, type CD-86; 8-volt leads, generator to set box.
  1 cord, type CD-88; three-conductor, set box to dry batteries.
  5 tubes, type VT-2 (spare).
  6 tubes, type VT-5 (spare).
  1 adapter, type FT-65 (spare).
  4 batteries, type BA-8 (2 spare).
  12 batteries, dry, No. 6 ignition closed-circuit type (9 spare).
  2 head sets, type P-11.
4 mast sections, type MS-2.
1 frame, type M-1.
1 cincha band, type ST-7.
2 straps, type ST-8 (three straps connected to ring).
2 straps, with snap hooks at each end.

NO. 3 MULE.

1 bag, type BG-6, including following parts:
  1 mast cap, type MP-4; complete with 50 feet of antenna lead-in wire.
  1 antenna, type AN-4; six 75-foot lengths antenna cord, complete with insulators and guy ropes.
  1 counterpoise, type CP-3; six 90-foot lengths counterpoise wire.
  13 reels, type RL-3; 6 for antenna, 6 for counterpoise, 1 for antenna lead-in.
  1 cord, type CD-89; set box to counterpoise, block type BL-2 on one end.
  2 connectors, type M-6; spares for antenna wires.
  1 insulator, type IN-4; electrose, mast bottom.

1 bag, type BG–6; including following parts:
- 1 bag, type BG–7, containing—
  - 2 hammers, type HM–1.
  - 6 stakes, type GP–2.
- 1 tool roll, type BG–10, containing—
  - 1 wrench, 4-inch, single end, $\frac{7}{16}$-inch opening.
  - 1 file, 4-inch, bastard, warding.
  - 1 file, 6-inch, bastard.
  - 1 knife, Empire No. 1013.
  - 1 pliers, round nose, 6-inch, side cutting.
  - 1 pliers, 6-inch, side cutting.
  - 1 handle, file.
  - 1 screw driver, 2-inch blade.
  - 1 screw driver, 4-inch blade.
  - 1 wrench, 9-inch, double end, $\frac{7}{8}$-inch and $1\frac{1}{16}$-inch opening.
  - 1 spool wire, copper, spare.
- 1 tent, type TN–1, with following parts rolled up inside—
  - 1 insulating device, type IN–13, for tent.
  - 14 stakes, wood, for tent.
  - 2 ropes, tent guys.
  - 1 plug, for tent adapter.
- 1 voltmeter, type I–10.
- 2 pounds wire, type W–7.
- 1 pound tape, friction $\frac{3}{4}$-inch.

1 mast section, type MS–1.
2 mast sections, type MS–2.
1 mast section, type MS–3.
1 ridge pole extension piece, for tent adapter.
2 tent pole extension pieces with spike in end, for tent adapter.
1 frame, type M–1.
1 cincha band, type ST–7.
2 straps, type ST–8 (three straps connected to ring).
2 straps with snap hooks at each end.

PARTS LIST OF SCR–127 SET.

(Arranged by equipment.)

1 equipment, type PE–28; power:
- 1 generator, type GN–29.
- 2 cranks, type GC–1.
- 1 stand, type GS–1.
- 1 hood, type BG–9; for generator.
- 4 bolts, type M–2; for generator stand.
- 2 plates, type M–3; for generator stand.

1 equipment, type RE–21; radio:
- 1 set box, type BC–7; u. w. radio telegraph.
- 4 legs for set box, type BC–7.
- 1 cord, type CD–87; 350-volt leads, generator to set box.
- 1 cord, type CD–86; 8-volt leads, generator to set box.
- 1 cord, type CD–88; 3-conductor, set box to dry batteries.
- 1 box, type BC–102; for batteries and accessories.
- 9 tubes, type VT–5; 3 in use, 6 spares.
- 4 adapters, type FT–65; 3 in use, 1 spare.
- 12 batteries, dry, No. 6 ignition closed-cirucit type, 3 in use, 9 spare.

1 equipement, type RE–21; radio—Continued.
- 4 batteries, type BA–8; 2 in use, 2 spare.
- 9 tubes, type VT–2; 4 in use, 5 spare.
- 2 head sets, type P–11.
- 1 voltmeter, type I–10.
- 1 tool roll, type BG–10.
- 1 wrench, 4-inch, single end, $\frac{7}{16}$-inch opening.
- 1 file, 4-inch, bastard, warding.
- 1 file, 6-inch, bastard.
- 1 knife, Empire No. 1013.
- 1 pliers, round nose, 6-inch, side cutting.
- 1 pliers, 6-inch, side cutting.
- 1 handle, file.
- 1 screw driver, 2-inch blade.
- 1 screw driver, 4-inch blade.
- 1 wrench, 9-inch, double end, $\frac{7}{8}$-inch and $1\frac{1}{16}$-inch opening.
- 1 spool wire, copper, spare.
- 2 pounds wire, type W–7.
- 1 pound tape, friction, $\frac{3}{4}$-inch.

1 equipment, type A–1–A; antenna:
- 1 mast section, type MS–1.
- 12 mast sections, type MS–2; 8 for mast, 3 for tent, 1 spare.
- 1 mast section, type MS–3.
- 1 insulator, type IN–4; electrose.
- 1 mast cap, type MP–4; complete with 50 feet of antenna lead-in wire (Spec. 3055–A).
- 1 antenna, type AN–4; six 75-foot lengths antenna cord, complete, with insulators and guy ropes.
- 1 counterpoise, type CP–3; six 90-foot lengths counterpoise wire.
- 1 cord, type CD–89; set box to counterpoise, block type BL–2 on one end.
- 13 reels type RL–3; 6 for antenna, 6 for counterpoise, 1 for antenna lead-in.
- 6 stakes, type GP–2.
- 2 hammers, engineers, 2 pounds, 2 face.
- 2 bags, type BG–6.
- 1 bag, type BG–7.
- 2 connectors, type M–6; spares for antenna wires
- 1 adapters, set of, for tent, 4 pieces.

3 frames, type M–1.
3 cincha bands, type ST–7.
6 straps, type ST–8 (three straps connected to ring).
6 straps, with snap hooks at each end.
1 equipment, type LE–1; tent:
- 1 tent, type TN–1.
- 14 stakes, wood, for tent.
- 2 ropes, guy, for tent.
- 1 insulating device.

TRANSPORTATION SCR–130 SET.

The following list shows how the material is to be packed for transportation:

9 batteries, type BB–14; lead, storage, 4-volt, 3 in use, 6 spare.
1 case, type BC–25–A, containing 1 dynamotor, type DM–1.

1 set box, type BC–7, including following parts:
- 4 tubes, type VT–2.
- 3 tubes, type VT–1.
- 1 instruction pamphlet.

1 box, type BC–102, including the following parts:
- 1 cord, type CD–91; 350-volt leads, dynamotor to set box.
- 1 cord, type CD–92; 12-volt leads, dynamotor to set box.
- 1 cord, type CD–88; 3-conductor, set box to dry batteries.
- 1 cord, type CD–90; 12-volt leads, set box to storage batteries.
- 3 cords, type CD-38; connecting storage batteries in series (1 spare).
- 4 tubes, type VT-1 (spare).
- 5 tubes, type VT-2 (spare).
- 4 batteries, type BA-8 (2 spare).
- 2 head sets, type P-11.

1 bag, type BG-6, including following parts:
- 1 mast cap, type MP-4; complete with 50-foot antenna lead-in wire.
- 1 antenna, type AN-4; six 75-foot lengths antenna cord, complete with insulators and guy ropes.
- 1 counterpoise, type CP-3; six 90-foot lengths counterpoise wire.
- 13 reels, type RL-3; 6 for antenna, 6 for counterpoise, 1 for antenna lead-in.
- 1 cord, type CD-89; set box to counterpoise, block type BL-2 on one end.
- 2 connectors, type M-6; spares for antenna wires.
- 1 insulator, type IN-4; electrose, mast bottom.

1 bag, type BG-6, including following parts:
- 1 bag, type BG-7, containing:
  - 2 hammers, type HM-1.
  - 6 stakes, type GP-2.
- 1 tent, type TN-1, with following parts rolled up inside:
  - 1 insulating device, type IN-13; for tent.
  - 14 stakes, wood, for tent.
  - 2 ropes, tent guys.
  - 1 plug, for tent adapter.
- 1 voltmeter, type I-10.
- 1 pliers, combination, 6-inch.
- 1 screw driver, 2½-inch blade.
- 2 pounds wire, type W-7.
- 1 pound tape, friction, ¾-inch.
- 1 mast section, type MS-1.
- 12 mast sections, type MS-2.
- 1 mast section, type MS-3.
- 1 ridge-pole extension piece, for tent adapter.
- 2 tent-pole extension pieces with spike in end for tent adapter.
- 4 legs for set box, type BC-7.
- 6 straps, type ST-5; for bundling mast sections.

PARTS LIST OF SCR–130 SET.

(Arranged by equipment.)

1 equipment, type PE-7; power:
- 9 batteries, type BB-14; lead, storage, 4-volt; approximately 100 ampere-hours at 10-ampere discharge rate; 3 in use, 6 spare.
- 1 case, type BC-25-A, carrying, for dynamotor.
- 1 dynamotor, type DM-1.

1 equipment, type RE-22; radio:
- 1 set box, type BC-7; u. w. radio telegraph.
- 4 legs for set box, type BC-7.
- 1 cord, type CD-91; 350-volt leads, dynamotor to set box.
- 1 cord, type CD-92; 12-volt leads, set box to dynamotor.
- 1 cord, type CD-90; 12-volt leads, set box to storage battery.
- 1 cord, type CD-88; 3-conductor, set box to dry batteries.
- 3 cords, type CD-38; connecting storage batteries in series, 2 in use, 1 spare.
- 1 box, type BC-102; for batteries and accessories.
- 7 tubes, type VT-1; 3 in use, 4 spare.
- 4 batteries, type BA-8; 2 in use, 2 spare.
- 9 tubes, type VT-2; 4 in use, 5 spare.
- 2 head sets, type P-11.
- 1 voltmeter, type I-10.
- 1 pliers, 6-inch combination.
- 1 screw driver, 2½-inch blade.
- 2 pounds wire, type W-7.
- 1 pound tape, friction, ¾-inch.
- 6 straps, type ST-5; for bundling mast sections.

1 equipment, type A-1-A; antenna:
- 1 mast section, type MS-1.
- 12 mast sections, type MS-2; 8 for mast, 3 for tent, 1 spare.
- 1 mast section, type MS-3.
- 1 insulator, type IN-4; electrose.
- 1 mast cap, type MP-4; complete with 50 feet of antenna lead-in wire.
- 1 antenna, type AN-4; six 75-foot lengths antenna cord complete with insulators and guy ropes.
- 1 counterpoise, type CP-3; six 90-foot lengths counterpoise wire.
- 1 cord, type CD-89; set box to counterpoise, block type BL-2 on one end.
- 13 reels, type RL-3; 6 for antenna, 6 for counterpoise, 1 for antenna lead-in.
- 6 stakes, type GP-2.
- 2 hammers, engineers, 2-pound, 2-face.
- 2 bags, type BG-6.
- 1 bag, type BG-7.
- 2 connectors, type M-6; spares for antenna wire.
- 1 adapters, set of, for tent, 4 pieces.

1 equipment, type LE-1; tent:
- 1 tent, type TN-1.
- 14 stakes, wood, for tent.
- 2 ropes, guy, for tent.
- 1 insulating device.

SIGNAL CORPS PAMPHLETS.

(Corrected to February, 1922.)

RADIO COMMUNICATION PAMPHLETS.

(Formerly designated Radio Pamphlets.)

No.

1. Elementary Principles of Radio Telegraphy and Telephony (edition of 4–28–21) (W. D. D. 1064).
2. Antenna Systems.
3. Radio Receiving Sets (SCR–54 and SCR–54–A) and Vacuum Tube Detector Equipment (Type DT–3–A).
5. Airplane Radio Telegraph Transmitting Sets (Types SCR–65 and 65–A).

No.
9. Amplifiers and Heterodynes (W. D. D. 1092).
11. Radio Telegraph Transmitting Sets (SCR–74; SCR–74–A)
13. Airplane Radio Telegraph Transmitting Set (Type SCR–73).
14. Radio Telegraph Transmitting Set (Type SCR–69).
17. Sets U. W. Radio Telegraph (Types SCR–79–A and SCR–99) (W. D. D. 1084).
20 Airplane Radio Telephone Sets (Types SCR–68; SCR–68–A; SCR–114; SCR–116; SCR–59; SCR–59–A; SCR–75; SCR–115).
22. Ground Radio Telephone Sets (Types SCR–67; SCR–67–A (W. D. D. 1091).
23. U. W. Airplane Radio Telegraph Set (Type SCR–80).
24. Tank Radio Telegraph Set (Type SCR–78–A).
25. Set, Radio Telegraph, Type SCR–105 (W. D. D. 1077).
26. Sets, U. W. Radio Telegraph (Types SCR–127 and SCR–130) (W. D. D. 1056) (edition of November, 1921).
28. Wavemeters and Decremeters, W. D. D. 1094.
30. The Radio Mechanic and the Airplane.
40. The Principles Underlying Radio Communication (edition of May, 1921) W. D. D. 1069.

WIRE COMMUNICATION PAMPHLETS.

(Formerly designated Electrical Engineering Pamphlets.)

1. The Buzzerphone (Type EE–1).
2. Monocord Switchboards of Units Type EE–2 and EE–2–A and Monocord Switchboard Operator's Set Type EE–64 (W. D. D. 1081).
3. Field Telephones (Types EE–3; EE–4; EE–5).
4. Laying Cable in the Forward Area (formerly designated Training Pamphlet No. 3).
6. Trench Line Construction (formerly designated Training Pamphlet No. 6–a).
7. Signal Corps Universal Test Set Type EE–65 (edition of December, 1921) (W. D. D. 1020).
10. Wire Axis Installation and Maintenance within the Division (W. D. D. 1068).

TRAINING PAMPHLETS.

1. Elementary Electricity (edition of 1–1–21 (W. D. D. 1055).
4. Visual Signaling.
5. The Homing Pigeon, Care and Training (W. D .D. 1000).
7. Primary Batteries (formerly designated Radio Pamphlet No 7).
8. Storage Batteries (formerly designated Radio Pamphlet No. 8).

FIELD PAMPHLETS.

1. Directions for Using the 24-CM. Signal Lamp (Type EE–7).
2. Directions for Using the 14-CM. Signal Lamp (Type EE–6).

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SETS, RADIO TELEPHONE AND TELEGRAPH

TYPES SCR-109-A AND SCR-159

Radio Communication Pamphlet No. 27

PREPARED IN THE OFFICE OF THE
CHIEF SIGNAL OFFICER

June, 1922

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WAR DEPARTMENT,
WASHINGTON, *June 30, 1922.*

The following publication, entitled "Sets, Radio Telephone and Telegraph, Types SCR–109–A and SCR–159," Radio Communication Pamphlet No. 27, is published for the information and guidance of all concerned.

[A. G. 062.1 (6–20–22).]

BY ORDER OF THE SECRETARY OF WAR:

JOHN J. PERSHING,
General of the Armies,
Chief of Staff.

OFFICIAL:
ROBERT C. DAVIS,
Acting The Adjutant General.

TABLE OF CONTENTS.

SETS, RADIO TELEPHONE AND TELEGRAPH.

(Types SCR–109–A and SCR–159.)

SECTION I.

PURPOSE OF SETS—RANGES.

1. *Purpose of sets—ranges.*—The SCR–109–A and SCR–159 are ground radio sending and receiving vacuum tube sets providing three means of communication—undamped wave radio telegraphy, buzzer modulated radio telegraphy, and radio telephony. The two sets differ only in the antenna equipment. Their range of transmitting wave lengths is from 300 to 500 meters and receiving wave length from 300 to 1,100 meters. The SCR–109–A set will furnish reliable communication with a similar set over a distance of 60 miles by undamped wave telegraphy; over a distance of 30 miles by buzzer modulated telegraphy; and over a distance of 20 miles by telephony. The SCR–159 set will furnish reliable communication with a similar set over a distance of 80 miles by undamped wave telegraphy; over a distance of 50 miles by buzzer modulated telegraphy; and over a distance of 30 miles by telephony. The minimum output of either set is 34 watts and under favorable circumstances the distances given above may be greatly increased.

SECTION II.

GENERAL DESCRIPTION OF SETS.

2. *Parts of set.*—Each set is composed of power, radio, and antenna equipment. The power and radio equipment of both sets are alike. The power equipment consists of twelve storage batteries and a dynamotor. The radio equipment is contained in two chests—one carrying both the radio transmitter and the radio receiver, the other carrying the auxiliary radio apparatus and spare parts, as well as the dynamotor. The SCR–109–A set is provided with a V antenna, each leg of which is 175 feet long. The SCR–159 set is provided with a 40-foot umbrella antenna. Appropriate counterpoises are furnished with each antenna.

3. *Transportation—weight and bulk.*—The sets are too heavy to be transported by hand, thus motor or wagon transport must be provided. The chest containing the radio transmitter, which is mounted in one box, and the radio receiver, which is mounted in another box, measures 13 by 35¼ by 17 inches high and weighs 35 pounds empty. This chest may be mounted upon the second chest and fastened to it by means of clamps provided. The second chest measures 13 by 35¼ by 17 inches high and weighs 28 pounds empty. It is provided with three main compartments, the dynamotor being carried in the middle compartment. The boxes containing the radio-transmitting and the radio-receiving apparatus are 9¼ by 16¼ by 14½ inches high and 9½ by 14¾ by 14½ inches high, respectively. Their respective weights are 30 and 25 pounds. The V antenna complete weighs 240 pounds, and has a bulk of 8 cubic feet. The mast sections are each 6 feet 10 inches long. The 40-foot umbrella antenna complete weighs 250 pounds and has a bulk of 12 cubic feet. Its mast sections are each 5 feet long. Each storage battery is 8 by 8 by 11 inches high and weighs 30 pounds. The dynamotor is 8¾ by 10 by 7¼ inches high and weighs 20 pounds. All figures given are approximate.

Section III.

DESCRIPTION OF POWER EQUIPMENT.

(Used in both sets.)

4. *Storage batteries.*—Twelve 4-volt storage batteries, type BB–28, are furnished with each set. These are 90-ampere-hour batteries of the lead acid type. Six batteries are in use at one time to furnish power. These are arranged in two groups in parallel, there being three batteries in series in each group. This arrangement provides a 12-volt, 180-ampere-hour source of power. Type BB–28 storage batteries have a nonspill plug. A compartment is provided in the cover of each battery for spare parts of this plug. For further information concerning storage batteries, see Signal Corps Training Pamphlet No. 8, entitled "Storage Batteries."

5. *Dynamotor.*—A dynamotor is provided for converting the 12-volt direct current furnished by the storage batteries to a 750–800-volt direct current. The motor takes 27 amperes at 12 volts; the output of the generator is approximately 0.2 of an ampere. The generator windings and terminals are well insulated, and all terminals are appropriately marked. The motor terminals are marked "+12 volts—"; the generator terminals are marked "+750 volts—." Lubrication is accomplished through dust-proof oil holes placed at

each end of the shaft. A 2-microfarad condenser, which is shunted across the generator terminals, is located in the base of the dynamotor.

Section IV.

DESCRIPTION OF ANTENNA EQUIPMENT.

6. *The* V *antenna* (*used in the SCR-109-A set*).—This antenna is a V-shaped antenna supported on three masts, each 20 feet high. The length of each leg is 175 feet. There is a lead-in wire 25 feet long. Each mast is made of three spruce sections, which are fitted with a spike at one end and a steel tube at the other to join with the next section. Six hundred feet of heavily insulated counterpoise wire is provided, which should be made in a V-shaped counterpoise with a third leg bisecting the V. The auxiliary antenna equipment comprises spare parts and such carrying rolls, reels, guy ropes, etc., as are needed to support or pack away the antenna. Ground mats, which may be used in place of the counterpoise under favorable conditions, are also a part of the antenna equipment.

7. *The umbrella antenna* (*used in the SCR-159 set*).—The umbrella antenna consists of six antenna wires each 50 feet long spread radially from the top of a 40-foot mast. At the end of each antenna wire there is attached a properly insulated guy rope, 95 feet long, by which the antenna wires are kept stretched out from the mast. The mast is composed of 10 spruce sections, each having a coupling tube to engage the next section. These sections are all alike except the top and bottom sections; the top section is fitted to receive the mast cap, the bottom section carries a heavy insulator on which it rests. The counterpoise system consists of six heavily insulated wires, each 90 feet long, radiating out from a central connecting block. Necessary spare parts and accessories are provided as a part of the antenna equipment.

Section V.

DESCRIPTION OF THE RADIO TRANSMITTER, TYPE BC-86-A.

(Used in both sets.)

8. *Exterior.*—The transmitting apparatus proper is all contained in a wooden box, the front of which is a bakelite panel upon which the various switches, controls, meters, and binding posts are

mounted. Figure 1 shows a view of this panel. At the upper left-hand corner is a milliammeter reading from 0 to 500 milliamperes which measures the plate current of the vacuum tubes used in the transmitter. To the right of this meter is a thermoammeter, reading from 0 to 2.5 amperes, which indicates the antenna current. In the upper right-hand corner is a 28-point dial switch controlling the number of turns of inductance included in the antenna circuit and hence controlling the transmitting wave length. Below this dial switch is a large four-pole double-throw switch marked "Transmit-

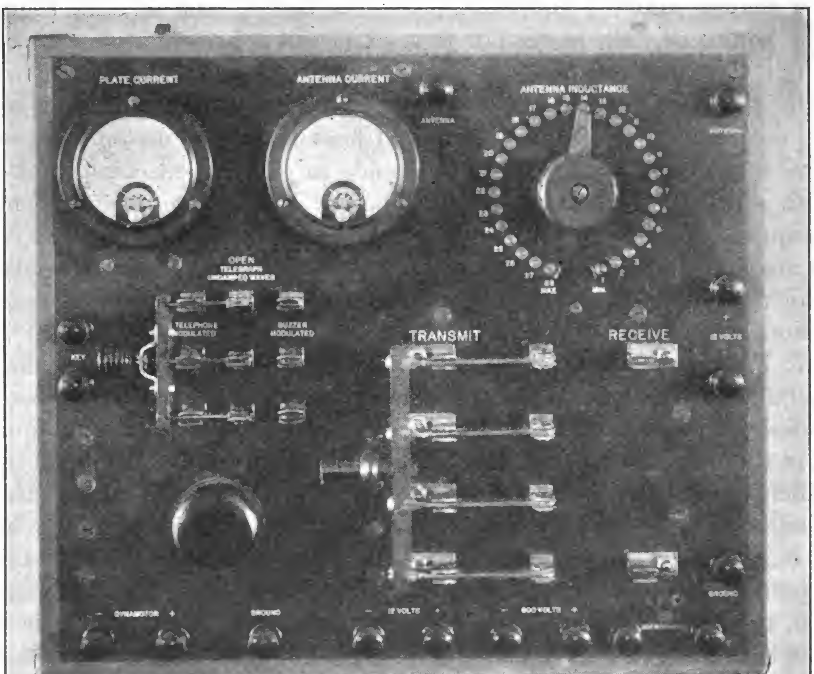

FIG. I.

Receive." When thrown to "Transmit" the upper blade connects the antenna to the transmitting apparatus; the second blade closes the 800-volt plate circuit; the third blade closes the circuit of the 12-volt supply of the dynamotor, thus causing it to start up; the bottom blade closes the filament circuit of the transmitting tubes. When thrown to "Receive," the upper blade connects the antenna to the receiving apparatus (in a separate box) and the lower blade closes the filament circuit of the receiver vacuum tubes.

Beneath the two ammeters is a small three-pole double-throw switch which must be considered as having three positions—closed to the left, closed to the right, and open. This switch is thrown to the left when it is desired to use radio telephony, to the right to use

buzzer-modulated telegraphy, and left open for undamped wave telegraphy. Each position of the switch is appropriately marked. The upper blade of the switch connects either the buzzer or the microphone; the middle blade, in either position, closes the filament circuit of the modulator and the speech amplifier vacuum tube; the lower blade when thrown to the "Telephone Modulated" side short-circuits the key. The buzzer used in buzzer-modulated telegraphy is mounted just below the three-pole switch.

There are four binding posts along the right-hand edge of the panel which are to be connected to similarly marked binding posts

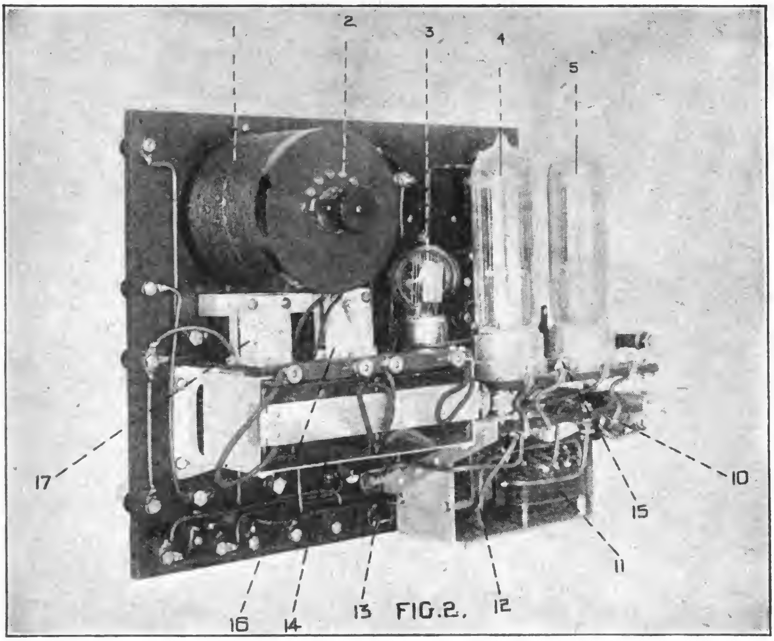

FIG. 2.

on the left-hand edge of the receiving apparatus. No cords are provided for these connections. The annunciator wire provided with the set should be used. On the left-hand edge of the panel is a pair of binding posts marked "Key," to which the key is connected by means of the proper cord. (Cord type CD–49.) The lower edge of the panel bears nine binding posts. The left-hand pair marked "—Dynamotor+" are to be connected to the motor (12-volt) side of the dynamotor; the next post marked "Ground" is to be connected to the counterpoise or ground; the next pair marked "—12 volts+" are to be connected to the storage batteries; the next pair marked "—800 volts+" are to be connected to the generator side of the dynamotor. The right-hand pair, marked "Microphone" are to have the microphone transmitter connected to them if it is not pro-

vided with the two-terminal plug to fit the jacks mounted directly above the binding posts. A cording diagram is shown in Figure 6.

9. *Interior.*—Access to the interior of the box is gained by removing a part of the back, sides, and top, which are joined together to form a cover and which are fastened to the box by clasps. The equipment inside the box is either directly attached to the rear of the panel or is mounted on brackets attached to the panel. By removing six machine screws, one located at each corner and one at the center of the top and bottom of the panel, the entire apparatus can be re-

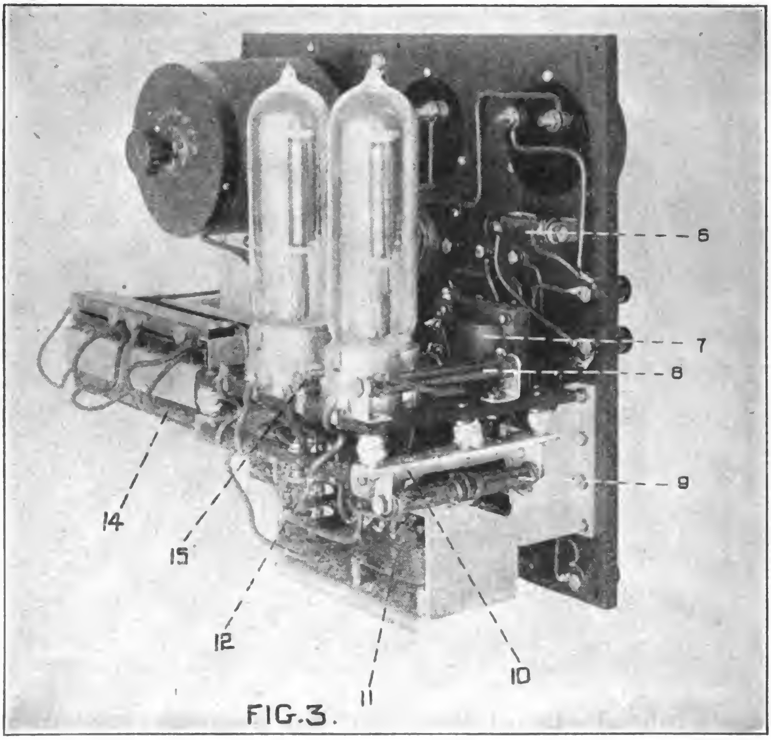

FIG. 3.

moved as a unit from the wood box. Interior views of the box are shown in Figures 2 and 3. The method of mounting of the various parts is clearly shown in the illustration. It is to be noted that the shelf carrying vacuum tubes is mounted on coiled wire spring shock absorbers. The plate-coupling control handle is placed on the inside of the box as shown at 2, Figure 2. In Figures 2 and 3 the numbers show apparatus as follows:

1. Oscillating circuit—inductance coil.
2. Variable inductance switch for plate coupling.
3. VT-2 speech amplifier tube.
4. VT-4 oscillator tube.
5. VT-4 modulator tube.

6. 5,000-ohm resistance across key.
7. Transformer (type C–51), secondary in grid circuit VT–2 speech amplifier, primary in microphone circuit.
8. 10,000-ohm resistance in series with plate circuit of VT–2 speech amplifier.
9. 10,000-ohm resistance, leak resistance for grid circuit of VT–4 oscillator tube.
10. Radio-frequency choke coil (type C–25) in series with leak resistance of grid circuit of VT–4 oscillator tube.
11. Transformer (type C–50) coupling plate circuit of VT–2 speech amplifier with grid circuit of VT–4 modulator tube.
12. Transformer (type C–50) coupling plate circuit of VT–4 modulator tube with plate circuit of VT–4 oscillator tube.
13. Radio-frequency choke coil (type C–25) in series with circuit supplying plate current to VT–4 oscillator tube.
14. BA–2 batteries used to supply negative grid biasing potential for VT–2 speech amplifier and VT–4 modulator tubes.
15. 0.2-megohm resistance (type RS–48) across secondary of transformers in grid circuit of VT–2 speech amplifier.
16. 1,500-mmf. condenser (type CA–93) used to block the high-voltage direct current on the plate of the VT–4 oscillator tube from reaching the grid.
17. 1,775-mmf. condenser (type CA–81) oscillating current condenser connected between the grid and the filament of the VT–4 oscillating tube.

Section VI.

DESCRIPTION OF THE RADIO RECEIVER, TYPE BC–98–A.

(Used in both sets.)

10. *Exterior.*—The receiving apparatus, consisting of a detector tube followed by two stages of audio-frequency amplification, is mounted in a wooden box having a bakelite panel for a front. This bakelite panel carries control handles and binding posts. A view of the front of the box is shown in Figure 4. Along the left-hand edge are four binding posts which are to be connected by annunciator or other suitable wire to similarly marked binding posts on the radio transmitter. Two binding posts on the upper right edge marked "+volts Aux. Plate Battery— " are provided in case it is necessary to use an external plate battery instead of the one that fits in the compartment provided in the interior. There are two binding posts marked "Aux. Tel." to which telephones may be attached if they are not provided with a plug to fit the jack located above the binding post. There are two such jacks, one for each headset provided with the set.

Control handles for the coupling between primary and secondary and for the tickler coil are located in the upper left hand part of the panel. The tickler control handle is in front of and concentric with the coupling control handle. Each has its properly marked

scale. The tickler, secondary, and primary inductance coils are mounted one within the other in the order named. Changing the coupling between the primary and secondary coils does not change the coupling between the secondary and the tickler coil.

Below the coupling control handle is mounted a three-point switch that controls the number of turns of the primary inductance coil in circuit. Below this is the control handle for the primary variable air condenser.

FIG. 4.

An eight-day clock of the automobile type is located in the upper right hand part of the panel. Below this are two switches; the one to the left, a two-point switch, controls the number of turns of the secondary inductance in circuit; the one to the right, a six-point switch, controls the amount of amplification. Below these switches is the control handle of the secondary variable air condenser.

11. *Interior.*—Access to the interior of the box is gained by removing part of the top, back, and sides which are joined to make a cover. This is fastened to the rest of the box by clasps. The method of mounting the equipment is very similar to that used in the radio

transmitter. A view of the interior is shown in Figure 5. The tubes are mounted upon a shelf which is supported by shock-absorbing springs. The two air condensers are shielded to avoid outside objects affecting their capacity. A spare grid leak resistance is fastened by spring clips to the inside of the cover. The reference numbers in the illustration refer to apparatus as follows:

1. Amplifying tubes (type VT–1).
2. Detector tube (type VT–1).

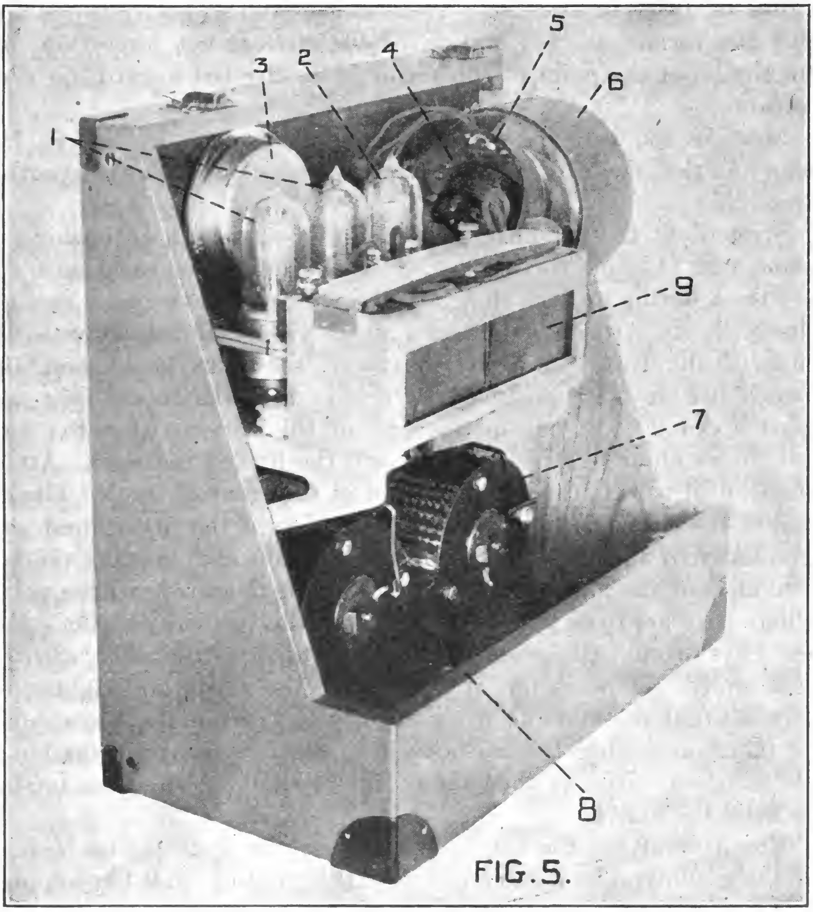

FIG. 5.

3. Eight-day automobile clock.
4. Tickler coil, coupled with secondary inductance.
5. Secondary inductance, coupled with primary inductance and with tickler coil.
6. Primary inductance, coupled with secondary inductance.
7. Primary variable air condenser (20 to 750 mmf.).
8. Secondary variable air condenser (20 to 750 mmf.).
9. Plate batteries (two type BA–2).

Section VII.

INSTALLING THE SETS.

12. *Erecting the antenna and ground system of the SCR–109–A set.*—The **V** antenna is used. This antenna can be installed for either of two purposes: (1) General use and (2) directional use. For the former the orientation of the wire is not important, but for the latter the point of the **V** should be directed toward the other station.

Measure the antenna wires to insure that each leg is 175 feet long and that the lead-in wire is 25 feet long. Correct any departure from this standard length.

Stretch out the antenna wires on the ground with an opening of about 60°. Couple three mast sections together for each mast and lay them on the ground alongside the wire and in the same straight line with it. Attach the antenna wires with their insulators to the tops of the three masts by means of the snap hooks and also attach two guys to each mast. Drive two ground stakes near each mast about 20 feet beyond the end of the wire, so that the guys will lie at an angle of about 45° with the line of the wire. Attach the lead-in wire to the antenna wires at the front of the **V**. Having raised the mast at the point of the **V**, raise the other mast tops gradually by using a light strain on the guys and, keeping the bottom ends of the masts on the ground, move them toward the points where they are to be when the mast is in the vertical position. Pass the guys around the ground stakes and take up the slack with the tent slides. If necessary, straighten up the masts and tighten the guys so that the antenna wires are nearly horizontal. Care should be taken in raising the masts to keep them in the prolongation of the antenna wires, as then there will be little or no stress tending to bend the masts.

For general use the three counterpoise wires should be laid out on the ground under the antenna with the point of the **V**-like arrangement near the radio transmitter. The counterpoise wires, each of which should be made 175 feet long, are arranged in a **V** with the third wire bisecting the angle made by the two legs of the **V**. For directional use the three wires should be laid out in the **V**-like arrangement with the point near the radio transmitter as before and with the free ends opening out toward the other station. The legs of the counterpoise are connected together electrically at the point of the **V**. Wherever possible the counterpoise wires should be sup-

ported on wood stakes about 1 foot high. This will give greater distance of transmission as well as better telephone communication.

Although ground mats are provided as a part of the antenna equipment, they are seldom used, for it is only under exceptional conditions that they will give as good results as the counterpoise. When used they should be buried under a few inches of earth, which should be well packed down on them. For general use the ground mats may be buried under the antenna wires. For directional use they should extend away from the radio transmitter toward the receiving station.

13. *Erecting the antenna and ground system of the SCR–159 set.*—At least five men are needed to erect the antenna. Three men are at the end of the antenna wires and guy ropes, two men raising the mast and adding the sections. The following directions should be observed:

Select clear space in which the antenna is to be erected. This clear space should be at least 200 feet in diameter. Place the mast and antenna equipment in the center of the space where the mast is to be erected. Take the top section (the one which has no iron pipe projecting from either end) and place the mast cap in one end of it. (The mast cap has eight sockets, which will hold the metal balls on the end of the antenna wires. It should have the 50-foot antenna lead-in wire permanently fastened to it.) Attach the six antenna wires to the mast cap by means of the ball and sockets provided. Unreel and lay out on the ground the six antenna wires and the guy ropes fastened to them. They should extend out radially from the mast, dividing the circle in equal parts—that is, they should make angles of 60° with each other.

Place a man at every other guy rope at the end of the guy rope. It is the duty of these three men to keep the mast upright as the sections are added. They do this by keeping the correct strain on the guy ropes, walking toward the mast as necessary. Select the eight other sections to be added (all alike) and the bottom section. (This has an insulator screwed on the bottom of it. If it is not screwed on, this should be done before adding the sections to the mast.) The mast will contain, when erected, 10 sections in all, 8 besides the top and bottom sections.

Add the sections, one man raising the mast directly upward and the other man adding the sections. Keep the mast upright, giving any directions that may be necessary to the men at the end of the guy ropes to do this. Having added all the sections, including the bottom one, allow the mast to rest on the ground. The two men at the mast then go out to the end of a guy rope and drive a stake in

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the ground and by means of the metal tent slide tighten the guy to the proper tension. This is done for each of the six guy ropes. Be careful that the mast is upright and that it is not bent. Make any changes in the strain on the guys necessary to insure this.

It is to be noted that on each guy rope there is an insulator between it and the antenna wire to which it is fastened. The rope is also divided by insulators. It is absolutely necessary that the antenna wires be well insulated. The antenna wires must not touch an object such as a tree, building, etc. The lead-in wire hangs down beside the mast.

Having erected the antenna, place the counterpoise connecting block on the ground near the mast. (This is fitted with holes in which the ends of the counterpoise wire are plugged.) A short wire leading to the set box is attached to it. Reel out the six counterpoise

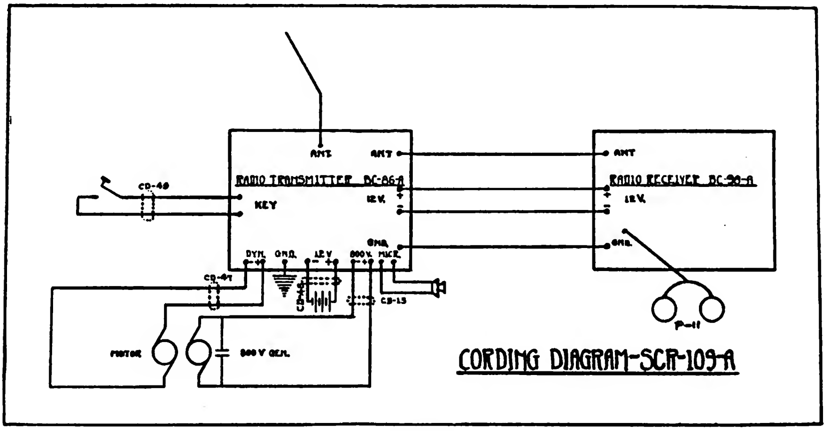

FIG. 6.

wires to their full extent, 90 feet. Each rests directly under an antenna wire. The counterpoise connecting block should be raised off the ground to properly insulate it. Wherever possible the counterpoise wires should be supported on wood stakes about 1 foot high. This will give greater distance of transmission as well as better telephone transmission.

14. *Installing the radio transmitting and receiving apparatus.*—A cording diagram is shown in Figure 6. The following directions should be observed:

a. Pull open the "Transmit-Receive" switch on the radio transmitter.

b. Remove the cover of the radio transmitter and place in the holder two BA-2 dry batteries. Connect the batteries to the terminals provided, being sure to observe the correct polarity as marked. Make all connections tight and clean. Fasten the batteries in place by the hinged clamp.

c. In a similar manner place two BA–2 dry batteries in the radio receiver. If no BA–2 batteries are available, an external 40-volt battery may be used. This should be connected with the proper polarity to the pair of binding posts on the radio receiver marked "+40 volt Aux. Plate Battery—."

d. Place in the radio transmitter a VT–4 vacuum tube in each of the two sockets, and a VT–2 tube in its socket. Leave off the cover of the radio transmitter, unless it is rainy or very damp.

e. Place in the radio receiver a VT–1 vacuum tube in each of the three sockets. Put on the cover of the radio receiver.

f. Connect in series three of the four-volt storage batteries, using the cords type CD–38. Similarly connect the other three four-volt storage batteries in series. Now connect these two sets of batteries in parallel. This is done by connecting the free *positive* terminal of the end battery in the first set to the free *positive* terminal of the corresponding battery in the second set; and by connecting the free *negative* terminal of the other end battery in the first set to the free *negative* terminal of the corresponding battery in the second set.

g. Using cord type CD–48, connect the storage batteries to the binding posts on the radio transmitter, marked "12 volts+." Observe the proper polarity. At the storage battery the positive end of the cord is attached to either of the two positive terminals that are connected together, and the negative end is attached to either of the two negative terminals that are connected together.

h. Connect by suitable lengths of annunciator wire (type W–7) the binding posts along the right-hand edge of the radio transmitter to the correspondingly marked binding posts along the left-hand edge of the radio receiver.

i. Connect the antenna lead-in wire to the binding post marked "Antenna" in the middle of the upper edge of the panel of the radio transmitter.

j. Connect the third binding post from the left at the bottom edge of the panel, marked "Ground," to the counterpoise block by means of the cord provided, if using the umbrella antenna. If using the V antenna, the binding post is connected by a piece of the counterpoise wire to the point of the V of the counterpoise.

k. Using cord type CD–47, connect binding posts on the radio transmitter marked "—dynamotor+" to the motor (12-volt) side of the dynamotor. Observe the proper polarity.

l. Using cord type CD–15, connect the binding posts on the radio transmitter marked "—800 volts+" to the generator (high voltage) side of the dynamotor. Observe the proper polarity.

m. Using cord type CD–49, connect the key to the binding posts marked "Key" on the radio transmitter.

n. Plug the microphone in the jacks provided in the radio transmitter. If no plugs are provided with the microphone, connect them to the binding posts beneath the jacks.

o. Plug the telephone receiver in one of the two jacks provided in the radio receiver. If a plug is not provided, connect the receiver to the binding post placed below the jacks. There is a right and wrong polarity for this connection to the binding post. To test for this connection, remove the cap of the telephone receiver and, using the diaphragm, test the strength of the permanent magnet of the receiver. Throw the "Transmit-Receive" switch to "Receive," thus causing the receiving vacuum tube to light up. If the strength of the magnet is increased, the telephones are connected with the right polarity.

SECTION VIII.

OPERATION AND CARE OF SETS.

15. *To transmit.*—Pull open the small three-pole double-throw switch on the radio transmitter. Throw the "Transmit-Receive" switch to the "Transmit" position, being sure to make good contacts by pushing it firmly into this position. The dynamotor should start and the oscillator tubes should light up. Turn the "antenna inductance" switch to that stud which will give the wave length desired. Close the key of the transmitter and adjust the plate current of the oscillator tube by means of the eight-point plate coupling control switch located at the rear of the inductance coil. Continue this adjustment until the plate current ammeter shows a reading of 125 milliamperes or the value nearest this that can be obtained. With this adjustment the antenna current should be approximately 1.5 amperes. If it is not known what stud is to be used to produce the wave length desired, and if the set has not been calibrated (see par. 17), it will be necessary to determine the setting of the antenna inductance by the aid of a wavemeter. (See Radio Communication Pamphlet No. 28.) In using a wavemeter, it is well to remember that the transmitter should always be adjusted so that its plate current is approximately 125 milliamperes before the reading is taken.

No matter what kinds of signals are to be transmitted, the above adjustment should always be made. The three-pole double-throw switch controls the circuits for the various kinds of signals.

To send undamped wave telegraph signals, leave the three-pole switch open and operate the key. Only the oscillator tube is lighted.

To send buzzer modulated telegraph signals, throw the three-pole switch to the "Buzzer Modulated" position. All three tubes should light up and the buzzer should give a clear note. Operate the key to transmit signals.

To transmit speech, throw the three-pole switch to the "Telephone Modulated" position. All three tubes should light up. Speak distinctly in the microphone, holding it in an upright position close to the mouth.

Under some conditions the plate current of the oscillator tube can be made more than 125 milliamperes. This should not be done except where the extra power is absolutely necessary in order to reach the distant station. The adjustment of the plate coupling control should be determined by the reading of the plate current ammeter and not by the reading of the antenna ammeter. If with proper plate current the antenna current is too low, the fault lies in the antenna system.

16. *To receive.*—The primary and secondary circuits must be tuned to each other in the usual way. When picking up damped wave, buzzer modulated, or radio telephone signals, the tickler coil should have zero coupling and the coupling between primary and secondary should be at maximum. The amplification control should be on the maximum position. When the signals are picked up the coupling between primary and secondary should be loosened and the tickler coupling increased. Continue this adjustment until clear signals are obtained without interference. The tickler coupling should be adjusted so that the detector tube is just at the point of oscillating. If it should oscillate—indicated by the character of the signal changing—the tickler coupling should be reduced gradually until the clear signal appears. Adjusting the coupling will to some extent throw the primary and secondary circuits out of resonance and hence these should be readjusted with every change in the coupling adjustment. After these adjustments have been made the amplification control may be changed to the stud that gives the best readable result. This control will oftentimes reduce interfering noises that can not be tuned out, including static, so that the desired signal may be read through the interference.

When receiving undamped wave telegraphy, all adjustments are much more critical than when receiving damped waves. *The setting of the tickler control coupling and secondary condenser is particularly critical.* For picking up undamped wave signals the tickler coupling should be placed near the maximum position. Make sure that the receiver is oscillating. Test by placing a wet finger

in the antenna lead-in. A distinct sound will be heard if the set is oscillating. As soon as the desired signal is picked up final adjustments must be made. The heterodyne note heard is changed in pitch by adjusting either the tickler, coupling, or secondary variables. These should be adjusted to give the best results as regards selectivity and pitch.

After an operator becomes familiar with the set he will learn to pick up buzzer modulated and telephone signals with his tickler set at a point just below that which will cause the set to oscillate, and to pick up undamped wave signals with the tickler set just above that point which will cause the set to oscillate.

It is very difficult to pick up signals unless the radio receiver has been calibrated. If not calibrated and a signal of a definite wave length must be received, it will be found much easier to pick up this signal if the receiving set is tuned to that wave length by the use of a wavemeter.

17. *Calibration of transmitter.*—As soon as possible after receiving the radio set it should be calibrated. A table should be made out as follows:

Wave length.	Primary inductance tap.	Plate coupling tap.	Plate current.	Antenna current.
....	1..........	....	....	....
....	2..........	....	....	....
....	3..........	....	....	....
....	Etc..........	....	....	....

In making the table, the *standard antenna* should be used, great care being taken to have the correct length of the lead-in wire as well as each antenna wire. Any change in the antenna will invalidate the table, so that thereafter no change should be made in the antenna when it is erected. When completed the table should be labeled as to the height of antenna, length of each antenna leg, length of lead-in wire, and kind of ground used. It should then be firmly attached to the inside of the cover of the transmitter box.

The best method of procedure to get data for the table is, having erected the antenna, to place the antenna inductance dial on tap 1 and then vary the plate coupling control until the plate current is 125 milliamperes. The plate coupling tap, the plate current, and the antenna current are to be noted in their proper columns. The wave length is then to be measured and noted in its column. This is repeated for each tap of the antenna inductance switch. It is advisable to get the average of three readings before making the permanent table.

In using the table, the first three columns are to be directly used, the fourth and fifth columns being a check upon the condition of the transmitting apparatus. The whole table should be frequently checked so that it will always be known to be correct.

18. *Calibration of receiver.*—Picking up signals is made much easier if the approximate setting of the control handles for any wave length is known. These settings should be determined by the use of a wavemeter and noted in a table as follows:

Wave length.	Primary induct-ance.	Primary con-denser.	Second-ary in-ductance.	Second-ary con-denser.	Coupler U. W. Tgh.	Tickler U. W. Tgh.	Coupler teleph-ony.	Tickler teleph-ony.
....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....

As in making the transmitter table, the standard antenna should be used and thereafter always erected without change. The completed table should be appropriately labeled and fastened to the inside of the receiver cover.

The first five columns can be filled in by the use of a wavemeter. Set the wavemeter oscillating at 300 meters and tune the primary and secondary circuits to resonance. Tune accurately and sharply, using a loose coupling. Note in the proper column the settings of the control handles. Repeat for 325 meters, 350 meters, etc., until the limit of wave length reception has been reached. The lower limit should also be determined and noted. It is advisable to get the average of three readings before making the permanent table.

The remaining four columns should be filled in as determined by settings when actually receiving signals from a distant station. It will be found that they can not be given a single accurate value. The limits of the value should be put in the column. For instance, it may be found for one wave length that the tickler coupling may vary from 4 to 7. This should be entered in the column thus: 4–7.

In using the table it must be remembered that the *settings are not final.* As soon as the signals are picked up, fine adjustment should be made. As previously noted, certain adjustments call for particular care.

19. *Notes on operation.*—For efficient operation, the SCR–109–A and SCR–159 sets require experienced operators who are familiar with the sets. If the operators are not familiar with the sets, it may be expected that at first only poor results will be obtained. The sets should be studied and their adjustments and peculiarities learned. The sets are capable of excellent transmission and reception. If a

set fails to operate satisfactorily the following points should be noted:

Carefully go over all connections made when installing the set. Check up as to correct connections, including correct polarity, and as to clean and tight connections.

Test the voltage of all batteries, both storage and dry.

See that the dynamotor is running properly and easily. See that it is properly oiled. The end covers of the dynamotor may be removed for ventilation if conditions are such that dirt, etc., will not get into the dynamotor.

Note that all switches make good contact. Press the double-throw switches firmly in their positions. *Clean their contacts frequently.*

Inspect the antenna. Check it as to correct length of legs and lead-in wire. See that the antenna wires are properly insulated. Improve the ground system if it admits of improvement.

When using the microphone, speak distinctly and directly into the transmitter. It is well to tap the transmitter smartly with the heel of the hand to make sure that its microphone element is not stuck.

Do not overlook the fact that the tickler adjustment is very critical, especially in receiving undamped wave radio telegraphy.

If the receiving set howls or sings try the same remedies you would on an amplifier. (See Radio Communication Pamphlet No. 9.)

In transmitting, if any of the three tubes fails to light, it may be due to a bad connection in the socket or a dirty contact pin. Clean the contact pin and replace the tube properly in the socket. If this does not remedy the defect, try a new tube. *In exchanging tubes always pull the "Transmit-Receive" switch so that it makes no contact.*

In receiving, all three of the tubes will light or none of them will, because their filaments are connected in series. Examine and clean the tube contact pins.

Sometimes a tube is defective. Find the defective one by trial of other tubes known to be in good condition.

Interchange the receiving tube until you have found the combination that works the best. Some tubes are better detectors than others. One of the receiving sockets is connected so that its tube is a detector.

In transmitting in an area where there is much traffic or under other conditions requiring an exact predetermined wave length, if your control settings have been made from the calibration curve, always check them by the aid of a wavemeter.

Be careful not to touch any of the metal parts of the transmitter when transmitting, as a shock will result. This applies particularly to the ammeters, the double-throw switches, and the various

inductance taps. Even when not transmitting, if the dynamotor is running, a shock is likely to be received. Thus it is well to *open the "Transmit-Receive" switch if it is necessary to make any adjustments other than by the control handles.*

In transmitting, unless it is rainy or very damp, the cover of the transmitter should be left off to allow plenty of ventilation for the VT-4 tubes.

In transmitting radio telephony, the plate current should continually vary. If it does not, the set is not working properly.

During a thunderstorm or other severe electrical disturbance, disconnect the antenna and ground wires from their binding posts and connect them directly to each other. This should always be done if the set is left installed without an operator being present.

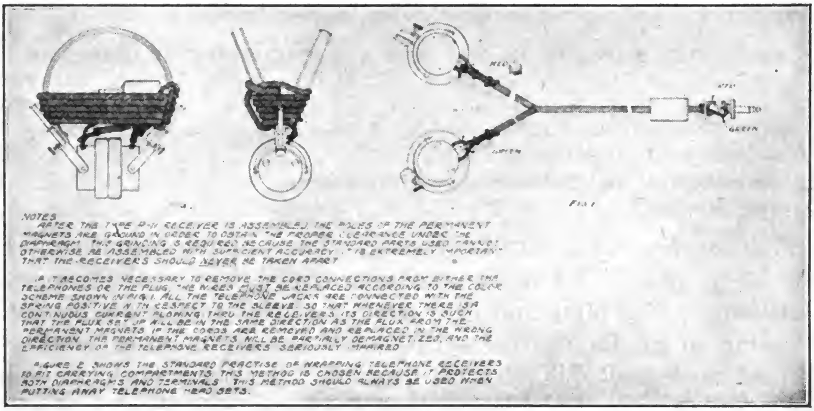

FIG. 7.

20. *Care of sets.*—The radio equipment must be handled with great care. The various parts are of delicate construction and rough handling will make the set inoperative. The transmitter and receiver boxes contain many parts closely packed together and with a great many connections. These are liable to become dislodged and the connection broken. The set should not be stored in a damp place nor unnecessarily exposed to rain. If the set becomes wet it should be carefully dried out but never exposed to intense heat.

The storage batteries must receive proper attention and care. (See Training Pamphlet No. 8.) The dynamotor panel should be kept clean and the dynamotor properly oiled. Use a good grade of oil and apply one or two drops after two hours' operation. It is important that not too much oil be used. It is much better to oil frequently with a small amount than to oil less frequently using a larger amount of oil.

The clock needs no attention other than winding and setting. It is wound by a key fastened at the top of the clock, access to which

is gained by turning the rim counterclockwise about 45° and pulling outward. The clock is set in the usual manner by pulling the key up until a click is heard.

Great accuracy has been observed in assembling the telephones and the microphone. There is a right and wrong polarity in connecting the cords of the telephones. If the cords are removed for any reason this must be taken into account in replacing them. Figure 7 shows the scheme of connection. The colors referred to in the figure are small, colored tracer threads running through the insulator. Figure 7 shows the standard practice of wrapping the telephones for storage. This method should always be followed. The microphone must be carefully handled and packed. It should need no other attention.

Section IX.

PRINCIPLES EMBODIED IN THE SETS AND THEIR CIRCUIT DIAGRAMS.

21. *Complete transmitting circuits.*—The radio transmitter, type BC–86–A, uses a VT–4 vacuum tube to produce radio-frequency oscillation. The plate and grid circuits of this tube use a capacity coupling in producing the oscillations. One of these capacities is a fixed condenser of 1,775 mmf. capacity; the other is the antenna used with the set. The antenna, therefore, is a factor in determining the wave length of the set, and its electrical constants should not differ from those of the standard antenna. A complete circuit diagram of the transmitter is shown in Figure 8. The circuits are best studied by simplified circuits of each kind of transmission.

22. *Undamped wave transmission.*—Figure 9 shows the simplified circuit for undamped wave transmission. The VT–4 tube generates radio frequency, there being a capacity coupling. The inductance is controlled by two dial switches, a 28-point switch connected to the antenna and used for changing the wave length, and an 8-point switch determining within certain limits the coupling of the oscillatory circuit to the plate. The latter adjustment enables a fairly constant output to be obtained over the working range of wave length and with some variation in the antenna characteristics.

Radio-frequency choke coils limit the radio-frequency current to the proper circuits. The plate current is supplied from an 800-volt generator in series with a telegraph sending key having a 5,000-ohm resistance in parallel with it. The grid of the tube is connected

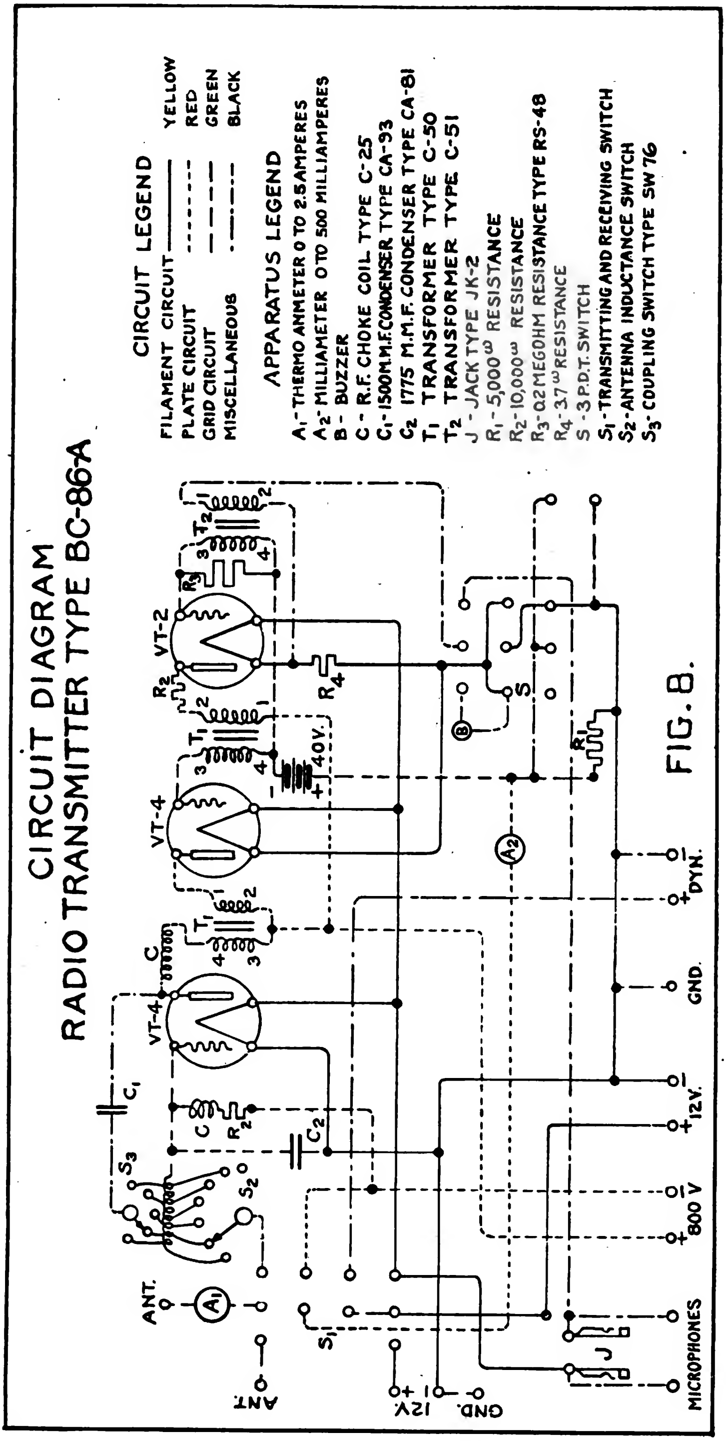
CIRCUIT DIAGRAM
RADIO TRANSMITTER TYPE BC-86-A
CIRCUIT LEGEND
FILAMENT CIRCUIT YELLOW
PLATE CIRCUIT RED
GRID CIRCUIT GREEN
MISCELLANEOUS BLACK
APPARATUS LEGEND
A_1 - THERMO AMMETER 0 TO 2.5 AMPERES
A_2 - MILLIAMETER 0 TO 500 MILLIAMPERES
B - BUZZER
C - R.F. CHOKE COIL TYPE C-25
C_1 - 1500 M.M.F. CONDENSER TYPE CA-93
C_2 1775 M.M.F. CONDENSER TYPE CA-81
T_1 TRANSFORMER TYPE C-50
T_2 TRANSFORMER TYPE C-51
J - JACK TYPE JK-2
R_1 - 5,000ω RESISTANCE
R_2 - 10,000ω RESISTANCE
R_3 - 0.2 MEGOHM RESISTANCE TYPE RS-48
R_4 - 37ω RESISTANCE
S - 3 P.D.T. SWITCH
S_1 - TRANSMITTING AND RECEIVING SWITCH
S_2 - ANTENNA INDUCTANCE SWITCH
S_3 - COUPLING SWITCH TYPE SW 76
VT-4
VT-4
VT-2
ANT.
ANT.
12V.
GND.
MICROPHONES
800 V
12V.
GND.
DYN.

FIG. B.

through a 10,000-ohm resistance to one side of the 5,000-ohm key resistance so that this key resistance is also in series in the direct current circuit between the grid and the filament. When the key is closed, the 5,000-ohm resistance is short-circuited and the grid potential is very nearly that of the negative side of the filament. Strong oscillations are then built up in the oscillatory circuit. When the key is opened the plate current has to pass through the 5,000-ohm resistance, causing a difference of potential to be established across the resistance so that a strong negative potential is placed on the grid, stopping the oscillations. The circuit therefore oscillates when the key is closed and stops oscillating when the key is opened. It will be noted that a 2 mf. condenser is placed across the 800-volt generator. This is contained in the base of the dynamotor.

SIMPLIFIED CIRCUIT – UNDAMPED WAVE TELEGRAPHY
RADIO TRANSMITTER TYPE BC-86-A

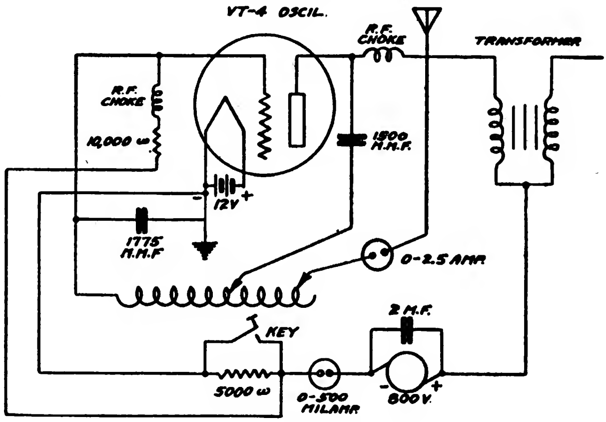

FIG. 9.

23. *Buzzer-modulated and radio-telephone transmission.*—Figure 10 shows the schematic circuit and apparatus when buzzer-modulated telegraph signals are transmitted. It will be noted that the VT–4 oscillator circuit, including the telegraph sending key, is the same as used for U. W. telegraph, but the VT–4 modulator tube and the VT–2 speech amplifier are now in use. The buzzer is operated steadily by utilizing the drop in potential across the 3.7-ohm resistance in series with the filament of the VT–2 tube. The telegraph sending key operates the same as for U. W. telegraph signals—by stopping oscillations when the key is opened, by reason of the large negative potential then impressed on the grid of the oscillator tube.

Figure 11 shows the schematic circuit and apparatus when telephone modulated signals are transmitted. The circuit of the VT–4

oscillator tube is still the same as for the other two conditions, except that the telegraph sending key is now short-circuited, and hence is not shown in the figure. The VT–4 oscillator is therefore producing oscillations continuously. A microphone transmitter is supplied

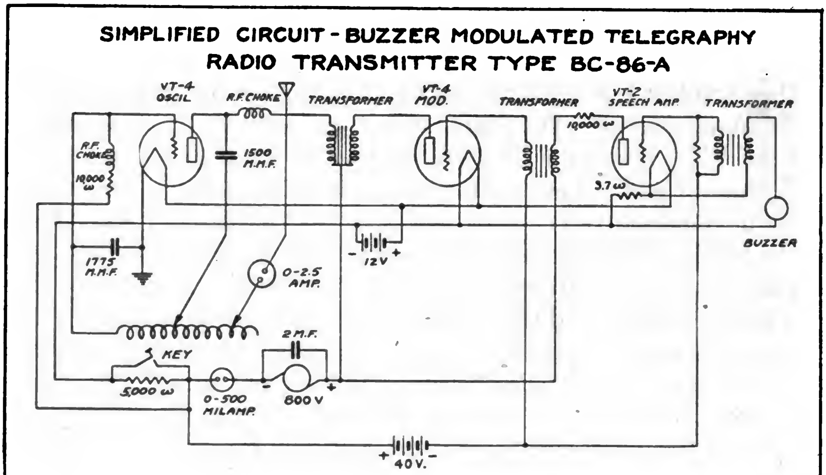

FIG. 10.

power by utilizing the voltage drop across the filament of the VT–2 tube.

The operation of the speech amplifier and modulator circuits is as follows, it being understood that the description applies to both

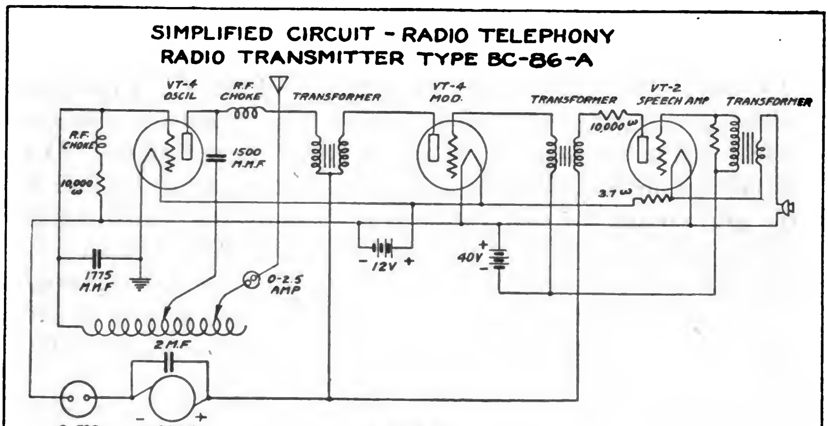

FIG. 11

the telephone-modulated and the buzzer-modulated telegraph conditions: Buzzer or voice frequency currents are set up in the primary circuits of the first transformer. The voltage set up across the primary is stepped up to a larger value by the secondary winding, and

this voltage is impressed upon the grid of the VT-2 speech amplifier. This tube operates as an amplifier, so the alternating current voltages on the grid appear in the plate circuit in amplified form but undistorted. The alternating current voltage in the plate circuit of the VT-2 tube is then transferred to the grid of the VT-4 modulator tube by means of a one to one ratio transformer. The audio-frequency voltage on the grid of the VT-4 modulator tube then appears further amplified in the plate circuit as evidenced by large variations in the plate current. The plate circuits of the VT-4 modulated tube and the VT-4 oscillator tube are coupled by means of a one to one ratio transformer. The windings are so connected that an *increase* in the modulator plate current will cause an *increase* in the oscillator plate current. The magnetic flux set up by current in the windings is more or less neutralized, so that the flux density in the core does not change greatly, and the core therefore does not become saturated. This is necessary to prevent distortion of currents set up by sound waves of large amplitude. The plate currents of the two VT-4 tubes then increase and decrease together in accordance with the voice or buzzer frequency. This variation of the oscillator plate current causes the radio-frequency oscillations generated by the tube to increase and decrease in amplitude so that the wave sent out from the antenna undergoes the voice or buzzer frequency modulation.

The current delivered by the 800-volt generator varies between wide limits, so the generator must be bridged by a condenser of at least 2 mf. capacity in order to prevent the inductance of the generator retarding the rapid change of plate current, and to prevent the self-induction of the generator causing the production of voltages across the generator sufficient to cause its breakdown.

The grids of the VT-2 speech amplifier and the VT-4 modulator tubes are given a negative biasing potential by a 40-volt battery, so that with normal excitation the grids never become positive. If the grids become positive with respect to the filament a current will flow in the grid circuit for that part of the cycle during which the grid is positive, and distortion of the impressed voltage will result.

The plate circuit of the VT-2 speech amplifier is supplied from the 800-volt generator, a 10,000-ohm resistance being placed in series with the circuit to limit the current to the proper value for a VT-2 tube.

A 0.2 megohm leak resistance is connected across the secondary of the transformer in the grid circuit of the speech amplifier tube in order to definitely limit the otherwise high impedance of the winding and thereby prevent tube blocking.

24. *Receiver circuits.*—The wiring diagram of the radio receiver is shown in Figure 12. The antenna circuit consists of a variable air

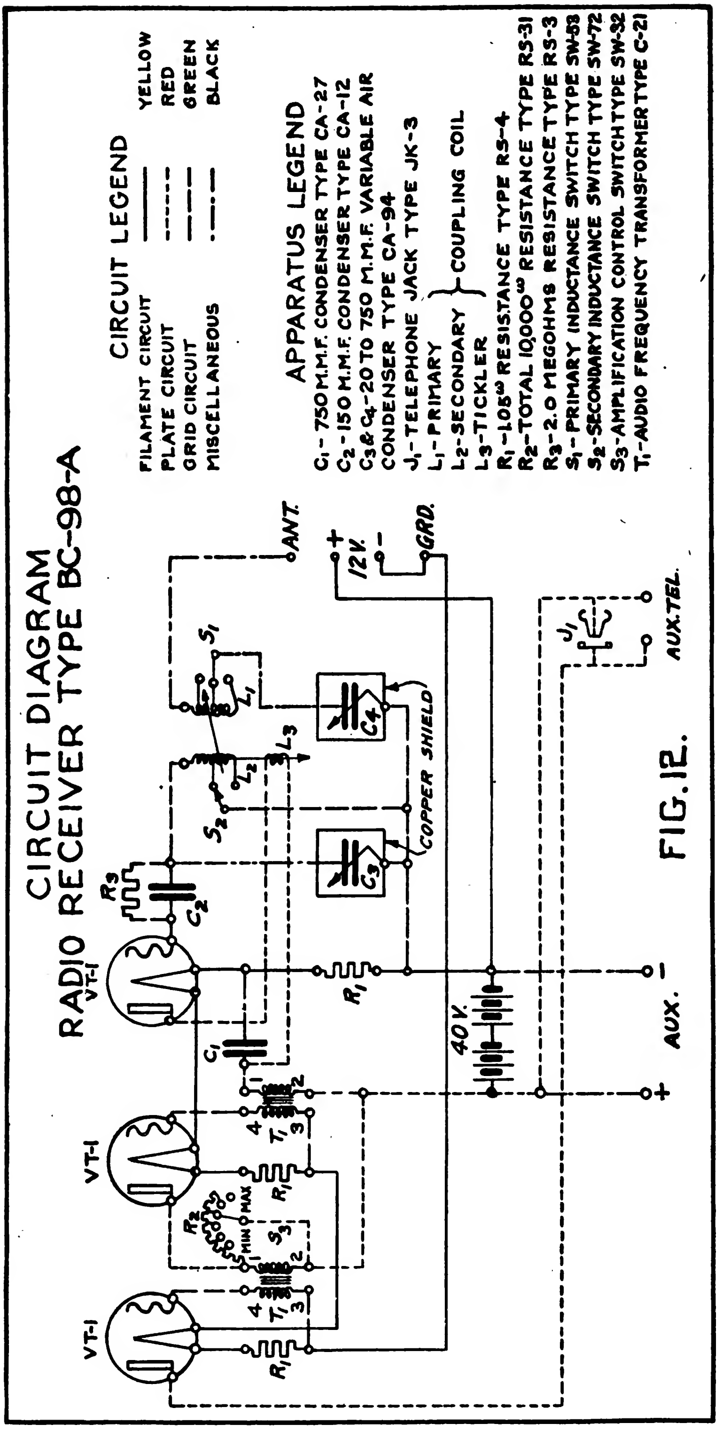
CIRCUIT DIAGRAM
RADIO RECEIVER TYPE BC-98-A
CIRCUIT LEGEND
FILAMENT CIRCUIT YELLOW
PLATE CIRCUIT RED
GRID CIRCUIT GREEN
MISCELLANEOUS BLACK
APPARATUS LEGEND
C1 - 750 M.M.F. CONDENSER TYPE CA-27
C2 - 150 M.M.F. CONDENSER TYPE CA-12
C3 & C4 - 20 TO 750 M.M.F. VARIABLE AIR CONDENSER TYPE CA-94
J1 - TELEPHONE JACK TYPE JK-3
L1 - PRIMARY
L2 - SECONDARY
COUPLING COIL
L3 - TICKLER
R1 - 1.05 RESISTANCE TYPE RS-4
R2 - TOTAL 10,000 RESISTANCE TYPE RS-31
R3 - 2.0 MEGOHMS RESISTANCE TYPE RS-3
S1 - PRIMARY INDUCTANCE SWITCH TYPE SW-53
S2 - SECONDARY INDUCTANCE SWITCH TYPE SW-72
S3 - AMPLIFICATION CONTROL SWITCH TYPE SW-32
T1 - AUDIO FREQUENCY TRANSFORMER TYPE C-21
ANT.
+ 12 V. -
GRD.
COPPER SHIELD
AUX. TEL.
VT-1
VT-1
VT-1
40 V.
AUX.
MIN
MAX

FIG. 12.

condenser and an inductance having three taps connected in series. This inductance is inductively coupled to a secondary circuit, consisting of an inductance having two taps and a variable air condenser. The grid circuit of the detector tube contains a grid leak resistance and a condenser. The proper positive grid biasing voltage is obtained by using the drop across the resistance in the filament circuits. The detector tube is followed by two stages of audio-frequency amplification coupled by audio-frequency iron core transformers. The plate circuit of the detector tube contains a tickler coil. By careful adjustment of the coupling between the tickler coil and the secondary inductance the detector circuit will be made regenerative, increasing the strength of spark and telephone signals. By increasing the tickler coupling still more the detector circuit will oscillate, permitting heterodyne reception of undamped wave telegraph signals. A switch on the front of the set box panel provides control of the amplification. This is accomplished by placing a variable shunt across the primary side of the audio-frequency transformer coupling the two amplifier tubes. A type P–11 head set is to be plugged into the jack in the plate circuit of the second amplifier tube. The plate current for all three tubes is supplied from a 40-volt battery consisting of two type BA–2 batteries connected in series, or may be supplied by an external 40-volt battery connected to the auxiliary binding posts provided. The filaments of the three type VT–1 tubes are connected in series and are supplied through the "Transmit-Receive" switch on the transmitting set box panel.

Section X.

SPECIAL WIRING FOR LONG-DISTANCE TRANSMISSION.

25. *Purpose of special wiring.*—It is possible to change the wiring of the radio transmitter so that the modulator tube is connected in parallel with the oscillator tube. This practically doubles the output of the set and hence greatly increases the distance of reliable undamped wave telegraph transmission. When the wiring of the set is changed for this purpose, it can not be used for buzzer-modulated telegraphy nor for radio telephony.

26. *Authority required to make the change.*—The change in the wiring should not be made unless absolutely necessary to obtain the

extra power for the distance over which communication must be maintained. Special authority of the signal officer of the unit must be obtained before the change is made. The work should be done by a competent radio electrician. The set should never be turned back to the depot without it being changed back to the standard wiring.

27. *Detailed instructions for making the change.*—The following directions should be strictly observed: The wiring diagram after changes have been made is shown in Figure 13. This should be compared with Figure 8. In Figure 13 the drawing items have the same labels and number as Figure 8, but with an exponent added to more clearly identify them. A study of the other illustrations of this pamphlet, as well as Figures 8 and 13, will aid in the identification. *Make only the specific changes listed.* These have been found to give the best results possible while permitting the set to be changed back to its standard wiring at any time.

$(VT\text{-}4)^1$ refers to VT-4 tube at left of diagram.

$(VT\text{-}4)^2$ refers to VT-4 tube at right of diagram.

R_2^1 refers to R_2 connected through choke coil C^1 to grid of $(VT\text{-}4)^1$. (This is the lower resistance tube at extreme right of set looking at the back of set.)

R_2^2 refers to R_2 connected to plate of VT-2 tube. (This resistance is just above resistance R_2^1 at extreme right of set looking at the back of set.)

C^1 refers to choke coil connected to grid of $(VT\text{-}4)^1$.

C^2 refers to choke coil connected to plate of $(VT\text{-}4)^1$.

T_1^1 refers to transformer T_1 connected to choke coil C^2 and plate of $(VT\text{-}4)^1$. (This transformer is left-hand one of the two large ones looking at the back of set.)

T_1^2 refers to transformer T_1 connected to grid of $(VT\text{-}4)^2$ through R_2^2 to plate of VT-2 tube. (This transformer is same size as the above and is at the right looking at back of the set.)

Using the above symbols, the following changes in connections should be made:

a. Remove connection from terminal 1 of transformer T_1^1 going to plate of $(VT\text{-}4)^2$.

b. Connect plate of $(VT\text{-}4)^2$ to plate of $(VT\text{-}4)^1$.

c. Connect together terminals 3 and 4 of transformer T_1^1. This will produce same results as if +800-volt lead was connected direct to choke coil C^2.

d. Remove connections from grid of $(VT\text{-}4)^2$ going to terminal 3 of transformer T_1^2.

e. Connect grid of $(VT\text{-}4)^2$ direct to grid of $(VT\text{-}4)^1$.

f. Remove +800-volt connection from terminal 1 of transformer T_1^2.

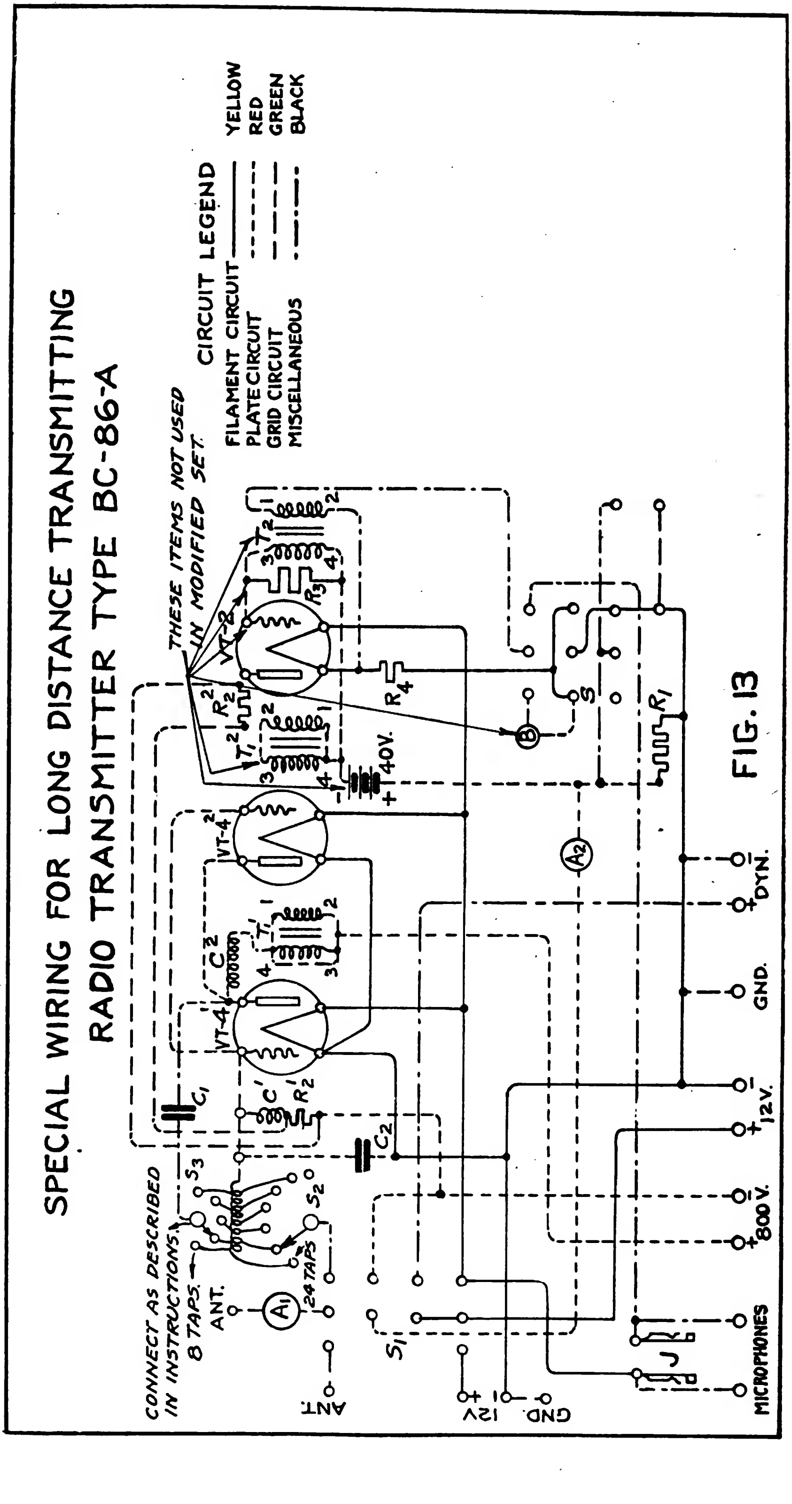
SPECIAL WIRING FOR LONG DISTANCE TRANSMITTING
RADIO TRANSMITTER TYPE BC-86-A
CIRCUIT LEGEND
FILAMENT CIRCUIT YELLOW
PLATE CIRCUIT RED
GRID CIRCUIT GREEN
MISCELLANEOUS BLACK
THESE ITEMS NOT USED IN MODIFIED SET.
CONNECT AS DESCRIBED IN INSTRUCTIONS.
8 TAPS
24 TAPS
ANT.
ANT.
12V
GND.
MICROPHONES
800 V.
12 V.
GND.
DYN.
40V.
VT-4
VT-4
VT-2

FIG. 13

g. Disconnect R_2^2 from plate of VT-2 and terminal 2 of transformer T_1^2.

h. Connect R_2^2 in parallel with R_2^1. This will make the resistance of the two in parallel 5,000 ohms. These two resistances are placed one directly over the other in the set as stated above.

i. Remove left filament lead of $(VT\text{-}4)^2$ going to three-pole double-throw switch at right.

j. Connect left filament terminal of $(VT\text{-}4)^2$ to left filament terminal of $(VT\text{-}4)^1$. That is, the filaments of $(VT\text{-}4)^1$ and $(VT\text{-}4)^2$ will be in parallel.

k. Remove back of antenna inductance. Disconnect all eight leads going from switch S_3 on back disk of antenna coil. Reconnect the eight leads of coupling switch S_3 to coil taps connected to following numbers on front panel: 4, 5, 6, 8, 10, 12, 14, and 16.

l. The switch contacts on front of the set are numbered; those on coupling switch at back of set are not numbered. Looking at the unnumbered contacts on the back of the set, the left-hand contact after the above change would be connected to the lead inside of the coil going to contact No. 4 on the front of the set. The next to the left contact on the back of the set will connect to the lead connected to contact No. 5 on front of set, etc., as enumerated in *k.*

m. For use with some antennae, the condenser at C_1 should have double its present capacity; that is, 3,000 mmf. New condensers of 3,000 mmf. should be installed if available after removing the condenser originally supplied in the set.

28. *Precautions necessary in using the modified set.*—In using the set after the changes outlined above have been made, care must be taken to overload as little as possible the output of the high-voltage side of the dynamotor. The current from the dynamotor is shown on the plate ammeter. Two hundred milliamperes is the normal output. With the two tubes in parallel the plate current will probably be between 250 and 400 milliamperes. The plate current can be kept at a minimum by taking care to adjust the coupling switch on the back of the antenna coil for minimum plate current and yet keep the antenna current at the desired value. If the plate current used for transmission is over 200 milliamperes, care should be taken that the key is kept closed no longer than necessary. It is believed a plate current of 300 to 350 milliamperes or over can be used safely for transmitting (measured when key is closed), as the average current during sending will not exceed one-half to two-thirds of the current with the key closed.

29. *Marking the modified set.*—Any sets modified described above should be tagged in some manner to show that they have been modified and can not be used for telephony or modulated telegraphy.

30. *Parts of modified set not in use.*—As indicated in Figure 13, certain parts of the set are not in use after it is modified. As these include the VT–2 tube and the 40-volt dry battery, they should be removed from the set.

Section XI.

PARTS LISTS OF SETS.

31. *Equipments in the SCR–109–A set.*—The SCR–109–A set comprises the following equipments:

One power equipment, type PE–36.
One radio equipment, type RE–19–A.
One antenna equipment, type A–9–B.

32. *Equipments in the SCR–159 set.*—The SCR–159 set comprises the following equipments:

One power equipment, type PE–36.
One radio equipment, type RE–19–A.
One antenna equipment, type A–14.

33. *Parts lists of above equipment.*—These equipments are made up of parts as noted below:

Power equipment, type PE–36:
- Battery, type BB–28; 12, 6 in use, 6 spare.
- Dynamotor, type DM–13; 1.

Radio equipment, type RE–19–A:
- Battery, type BA–2; 8, 4 in use, 4 spare.
- Chest, carrying, type BE–49; 1, for radio transmitter and receiver.
- Chest, carrying, type BE–50; 1, for spare parts and accessories including dynamotor.
- Cord, type CD–15; 1, transmitter to high voltage side of dynamotor.
- Cord, type CD–38; 8, for storage battery connections.
- Cord, type CD–47; 1, transmitter to low voltage side of dynamotor.
- Cord, type CD–48; 1, transmitter to storage batteries.
- Cord, type CD–49; 1, transmitter to key.
- Head sets, type P–11; 2.
- Key, type J–12 or J–2; 1, telegraph sending.
- Pliers, side cutting, 6-inch; 1 pair.
- Radio receiver, type BC–98–A; 1.
- Radio transmitter, type BC–86–A; 1.
- Screw driver, electricians, 3-inch blade; 1.
- Tape, friction, $\frac{3}{4}$-inch; 1 pound.
- Transmitter, type T–3; 1, microphone.
- Tube, type VT–1; 6, 3 in use, 3 spare.
- Tube, type VT–2; 2, 1 in use, 1 spare.
- Tube, type VT–4; 4, 2 in use, 2 spare.
- Wire, type W–7; 2 pounds.

Antenna equipment, type A–9–B (V antenna):
- Antenna, type AN–8–A; 2, on 2 reels, 1 in use, 1 spare.
- Bag, type BG–12; 2, carrying.
- Cord, type RP–3; sash No. 5, olive drab, 300 feet.
- Guy, type GY–4; 8, complete on 4 reels, 6 in use, 2 spare.
- Hammer, 2-pound crosspein; 1.
- Insulator, type IN–10; 4 spare.
- Mast section, type MS–14; 12, 9 in use, 3 spare.
- Mat, type M–5; 3, ground.
- Pliers, combination, 6-inch; 1 pair.
- Reel, type RL–3; 10 hand, 4 for counterpoise, 4 for guys, 2 for antennas.
- Roll, type M–15; 1, carrying.
- Stake, type GP–8; 12 ground, 6 in use, 6 spare.
- Tape, friction; 1 roll.
- Wire, type W–4; 50 feet, lead-in.
- Wire, type W–24; 750 feet on a spool, antenna.
- Wire, type W–30; 600 feet, on 4 reels, counterpoise.

Antenna equipment, type A–14, 40-foot umbrella:
- Antenna, type AN–12; 1, six 50-foot wires with insulators and cords attached.
- Bag, type BG–6; 2, carrying.
- Bag, type BG–7; 1, carrying.
- Connector, type M–6; 2 spares for antenna wires.
- Cord, type CD–94; 1, to counterpoise. Insulator block BL–2 on one end.
- Counterpoise, type CP–3; 1, six 90-foot wires.
- Hammer, 2-pound crosspein; 2.
- Insulator, type IN–4; 1, for bottom of mast.
- Mast cap, type MP–4; 1, with 50 feet lead-in wire.
- Mast section, type MS–1; 1, top.
- Mast section, type MS–2; 8, intermediate.
- Mast section, type MS–3; 1, bottom.
- Reels, type RL–3; 13, 6 for antenna, 6 for counterpoise, 1 for lead-in.
- Stakes, type GP–2; 6, ground.
- Straps, type ST–5; 6, for bundling mast sections.

SIGNAL CORPS PAMPHLETS.

(Corrected to June 1, 1922.)

RADIO COMMUNICATION PAMPHLETS.

(Formerly designated Radio Pamphlets.)

No.

1. Elementary Principles of Radio Telegraphy and Telephony (edition of 4–28–21). (W. D. D. 1064.)
2. Antenna Systems.
3. Radio Receiving Sets (SCR–54 and SCR–54–A) and Vacuum Tube Detector Equipment (Type DT–3–A).
5. Airplane Radio Telegraph Transmitting Sets (Types SCR–65 and 65–A).
9. Amplifiers and Heterodynes. (W. D. D. 1092.)
11. Radio Telegraph Transmitting Sets (SCR–74; SCR–74–A).
13. Airplane Radio Telegraph Transmitting Set (Type SCR 73).
14. Radio Telegraph Transmitting Set (Type SCR–69).

17. Sets, U. W. Radio Telegraph (Types SCR-79-A and SCR-99). (W. D. D. 1084.)
20. Airplane Radio Telephone Sets (Types SCR-68; SCR-68-A; SCR-114; SCR-116; SCR-59; SCR-59-A; SCR-75; SCR-115).
22. Ground Radio Telephone Sets (Types SCR-67; SCR-67-A). (W. D. D. 1091.)
23. U. W. Airplane Radio Telegraph Set (Type SCR-80).
24. Tank Radio Telegraph Set (Type SCR-78-A).
25. Set, Radio Telegraph, Type SCR-105 (W. D. D. 1077).
26. Sets, U. W. Radio Telegraph, Types SCR-127 and SCR-130. (W. D. D. 1056.)
27. Sets, Radio Telephone and Telegraph, Type SCR-109-A and SCR-159. (W. D. D. 1111.)
28. Wavemeters and Decremeters. (W. D. D. 1094.)
30. The Radio Mechanic and the Airplane.
40. The Principles Underlying Radio Communication (edition of May, 1921). (W. D. D. 1069.)

WIRE COMMUNICATION PAMPHLETS.

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3. Field Telephones (Types EE-3; EE-4; EE-5).
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6. Trench Line Construction (formerly designated Training Pamphlet No. 6-a).
7. Signal Corps Universal Test Set, Type EE-65. (W. D. D. 1020.) (2d edition.)
10. Wire Axis Installation and Maintenance Within the Division. (W. D. D. 1068.)
11. Elements of the Automatic Telephone System. (W. D. D. 1096.)

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2. Instructions for Using the Cipher Device, Type M-94. (W. D. D. 1097.) *For official use only.*
4. Visual Signaling.
7. Primary Batteries (edition of 6-9-22). (W. W. D. 1112.)
8. Storage Batteries (formerly designated Radio Pamphlet No. 8).

FIELD PAMPHLETS.

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2. Directions for Using the 14-cm. Signal Lamp (Type EE-6).

TRAINING REGULATIONS.

(Signal Corps subjects.)

450-190—Elements of Cryptanalysis.

O

WAVEMETERS AND DECREMETERS

Radio Communication Pamphlet No. 28

PREPARED IN THE OFFICE OF THE
CHIEF SIGNAL OFFICER

January, 1922

WASHINGTON
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1922

CERTIFICATE: By direction of the Secretary of War the matter contained herein is published as administrative information and is required for the proper transaction of the public business.

WAR DEPARTMENT

Document No. 1094

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WAR DEPARTMENT,
WASHINGTON, *January 17, 1922.*

The following publication, entitled "Wavemeters and Decremeters," Radio Communication Pamphlet No. 28, is published for the information and guidance of all concerned.

[062.1, A. G. O.]

BY ORDER OF THE SECRETARY OF WAR:

JOHN J. PERSHING,
General of the Armies,
Chief of Staff.

OFFICIAL:
P. C. HARRIS,
The Adjutant General.

TABLE OF CONTENTS.

WAVEMETERS AND DECREMETERS.

RADIO COMMUNICATION PAMPHLET NO. 28.

SECTION I.

USES OF WAVEMETERS AND DECREMETERS.

1. Definitions and uses.—A *wavemeter* is a radio frequency instrument used (1) to measure the length of electro-magnetic waves generated by some other circuit; (2) to emit, as a low-power transmitter, waves of a known length; (3) with the help of other apparatus to measure the inductance of a coil, the capacity of a condenser, etc.; and (4) in certain special cases, to measure the logarithmic decrement of the waves. A *decremeter* is a special type of wavemeter which can function in all respects like a wavemeter and in addition has a direct reading scale which can be used to measure the logarithmic decrement of a transmitter. Both are thus calibration instruments which are useful in the field and the laboratory.

A wavemeter or decremeter can be used either at a transmitting or a receiving station, where (1) an unknown wave length can be measured; (2) the circuits can be set at any predetermined wave length; (3) the circuits can be calibrated over their scales of wave lengths; and (4) the logarithmic decrement of a transmitter can be measured in the case of certain wavemeters.

SECTION II.

FUNDAMENTAL PRINCIPLE OF WAVEMETERS; FORMULAE.

2. Fundamental principle.—The fundamental principle upon which all wavemeters operate is the same. The meter almost invariably contains three essential elements: (1) A coil as an inductance; (2) a condenser, as a capacity; and (3) auxiliary apparatus that varies with the use to which the meter is to be put. A circuit of inductance and capacity has a certain natural frequency of oscilla-

tion, or natural wave length, which depends upon the values of the inductance and capacity. In a meter these are known and the wave length can be accurately computed from their values. By varying the capacity or the inductance, the wave length of the meter can be changed so as to bring it into resonance with another circuit. As the wave length of two circuits at resonance is the same, the wave length of the circuit under measurement thus becomes known. The general circuit diagram of a wavemeter is shown in figure 1.

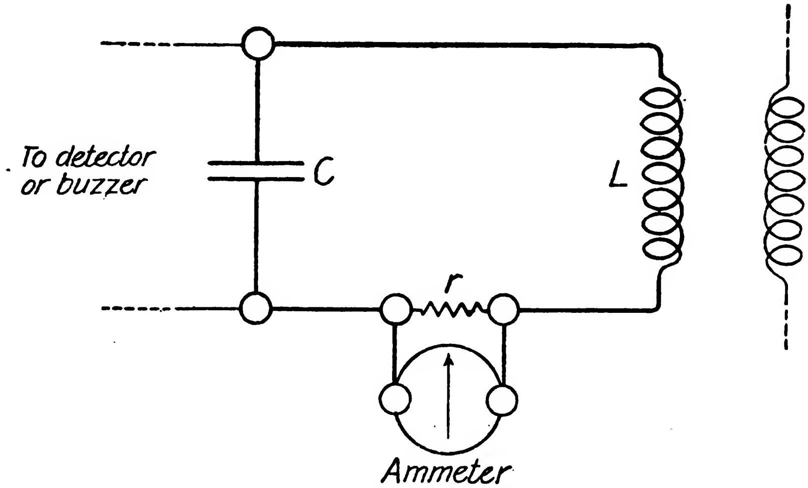

FIG. 1

3. Fundamental formulae.—The fundamental formula for the computation of the wave lengths of a meter with its known inductance and capacity is as follows:

$$\lambda=\frac{2\pi V}{\sqrt{\frac{1}{LC}-\frac{R^2}{4L^2}}}$$

where λ (read "lambda") is the wave length,

π (read "pi") 3.14,

V Velocity of light, 3×10^8 meters per second,

L Inductance of the coil,

C Capacity of the condenser,

R High frequency resistance of the circuit,

all to be expressed in a consistent system of units. In all practical cases the quantity $\frac{R^2}{4L^2}$ is so small as compared with $\frac{1}{LC}$ that it can be neglected in comparsion with it, so that the formula simplifies to

$$\lambda=2\pi V\sqrt{LC}$$

This formula can be expressed in many different systems of units, of which only the one in most common use will be given here:

If λ is in meters, L in milli-henrys, and C in microfarads, then

$$\lambda = 59{,}600 \times \sqrt{LC} \text{ meters.}$$

A numerical example in the use of the formula is as follows:

Let L be 0.040 milli-henrys.

And C 0.004 micro-farads.

Then $L \times C$ is 0.00016.

And $\sqrt{LC}$ is 0.01265.

And hence λ is $59{,}600 \times 0.01265$, or 754 meters.

Section III.

COMPONENT PARTS OF WAVEMETERS.

4. General design features.—A wavemeter may be set at any one of its wave lengths by varying either (1) the capacity of its condenser, or (2) the inductance of its coil. If the capacity is variable, then generally the inductance is constant, and similarly if the inductance is variable, the capacity is constant. The design of the inductance and capacity should be such that their high-frequency resistances are as low as possible, so that the losses in the wavemeter circuit are small. In general, the smaller these losses the more sensitive is the wavemeter, the sharper its tuning to resonance, and the lower its decrement, as will be explained in later paragraphs.

4a. Capacity.—If a variable capacity is used, it is almost always an air condenser, with a continuous change from a certain minimum, which is not zero, to a maximum value. The design and construction should be such that the internal losses at high frequency are as small as possible; thus a good contact must be made between all the fixed plates and also between all the moving plates; there should be no material between the fixed and moving plates or elsewhere in circuit, where the electric field of the charged plates may cause the flow of wasteful high-frequency currents, etc. The handle of the variable condenser carries a pointer for reading either on a scale of wave lengths or a scale of degrees or numbers. Some wavemeters have both these scales. As the maximum value of the capacity may

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be perhaps 20 or more times greater than the minimum, and as the wave length increases as the square root of the capacity (see paragraph 3), the longest wave length on a scale may be $\sqrt{20}$, or about 4.5 times the shortest wave length. In some types of condensers there are two sets of fixed and moving plates in the space usually occupied by a single set of each. This design permits the moving plates to be mechanically balanced; and also gives a larger change in capacity from minimum to maximum than in the usual condenser, and hence a longer scale of wave lengths for any given coil. The condensers are often contained in a compartment with a metal lining, on which the fixed or moving plates may be grounded, which shields the condenser from the influence of outside circuits and keeps the capacity more nearly constant as the meter is being handled by the operator.

4b. Inductance.—If a variable *inductance* is used, it is almost always in the form of a variometer with a continuous change from a certain minimum, which is not zero, to a maximum value. In general, a variometer consists of two coils connected in series, one of which is smaller than the other and is rotatable within it. When the two coils are in the same plane and the direction of the current is the same in both coils, the inductance is a maximum; and when the smaller one has been turned through 180 degrees and the current is in opposite directions in the two coils, the inductance is a minimum but is not zero. At intermediate positions the inductance has intermediate values. The wire used in the variometer should be of low resistance so that its high frequency loss is as small as possible. In some meters a special low resistance wire, know as "Litzendraht," consisting of a large number of separately insulated fine wires, is used. It has been found best not to use a large inductance for long waves and taps on it for short waves, but rather to use a set of coils each adapted to a different range of wave lengths. In explanation it may be stated that actual experience has shown that if there are "dead ends" of a coil in the magnetic field of the active coil, high frequency currents will be induced in them which will cause losses therein and change the inductance of the coil. When a set of coils is used, it is evidently necessary that the choice of coils be such that with the given condenser, the different ranges or scales overlap so as to include all wave lengths within the range of the wavemeter.

In some types of wavemeters, the coil is contained within the set box of the wavemeter. As it is necessary to know where the coil windings are in order to be able to make the proper coupling with the coil of the circuit under measurement, the plane of the windings or "Plane of coil" is generally marked by an arrow on the box. Sometimes the "Axis of coil," which is perpendicular to the plane of the windings, is marked instead of the "Plane of coil."

5. Auxiliary apparatus.—The auxiliary apparatus depends entirely upon the use to which the meter is to be put. At a transmitter the wavemeter is used as a receiver and the auxiliary apparatus is some device which indicates when the transmitter and the wavemeter are in resonance. At a receiver the wavemeter is used as a low power damped wave transmitter and the auxiliary apparatus is almost always a buzzer driven by a dry cell battery which furnishes the power to the meter. The circuits of the receiver and the wavemeter are tuned to resonance, which fact is indicated by the detector of the receiver.

5a. Resonance indicators.—When the wavemeter is used at a transmitter, the resonance indicator may be any one of the following devices, depending on the character of the transmitter, as will be explained in later paragraphs: (1) Hot-wire ammeter; hot-wire wattmeter; thermo-couple and galvanometer or thermo-galvanometer; miniature lamp, etc.; or (2) crystal detector and telephone; vacuum-tube detector and telephones, etc. If the device is of low resistance, as an ammeter, wattmeter, etc., as mentioned in (1), it is connected in series in the wavemeter circuit. Although the ammeter, etc., may be of only a few ohms resistance, yet in some cases even this may be too high a resistance to be included in series and it is therefore shunted by a resistance, so that the joint resistance is much reduced. (See Fig. 1.) It is evident that the shunt must be carefully chosen, for if it is of *very low* resistance, only a very small current will flow through the ammeter, etc., and the sensitivity of the wavemeter will be seriously reduced. Most meters are provided with an adjusting screw so that the needle can be set on the zero mark, but this is not absolutely necessary.

If the device is of high resistance, as a crystal detector and telephones, etc., in (2) of the previous paragraph, they are connected in shunt to the wavemeter circuit as in figure 1. In the shunt circuit (1) the detector and telephone may be in series; or (2) the telephones may be in shunt to the detector and the two in series with a small condenser. In the so-called "Unipolar" connection the telephones are in shunt to the detector and the two connected by a single wire to one terminal of the wavemeter. Although this connection is less sensitive than the usual type, it has the possible advantage of adding less outside capacity to that of the variable condenser than any other connection. In some cases the metal lining of the condenser compartment and the machine screws on the panel are used as a convenient means of connecting parts of the detector circuit and for this reason the meter will be inoperative unless it is assembled with all parts in place.

Although a wavemeter with a crystal detector, etc., is much more sensitive than one with an ammeter, galvanometer, etc., yet it is not

generally as useful as the latter type for the following reasons: The ammeter, etc., is operated by every type of spark and continuous wave transmitter, whereas the detector and telephones are operated only by spark transmitters, and those types of continuous wave transmitters that are modulated at an *audio* frequency. Many meters of recent design, therefore, are provided with an ammeter, galvanometer, etc., but not with a detector. However, in a few cases binding posts at the terminals of the condenser have been added so that a detector, etc., can be connected into circuit if desired.

5b. Buzzer.—When the wavemeter is used at a receiver, a buzzer operates or excites the wavemeter so that it acts as a low-power, damped wave transmitter giving wave trains at an audio frequency. Its action may be explained as follows: A buzzer in series with a battery is connected to the terminals of the meter and at each break at the buzzer contacts, part of the energy of the buzzer circuit is released to charge the condenser of the meter; the condenser then discharges through the coil of the meter; and thus the circuit is set into oscillation at a known wave length corresponding to the known values of its inductance and capacity. Most meters are provided with a battery compartment and the insertion of a battery in place automatically makes the necessary connections. In some cases the metal lining of the condenser compartment and the machine screws on the panel are used as a convenient means of connecting parts of the buzzer circuit as well as the detector circuit, and for this reason the meter will be inoperative unless it is assembled with all parts in place.

6. Wave-length scales.—As the range of wave length in meters with any *one* coil, or with any *one* condenser is limited, many meters are provided with a set of coils or condensers so that their range is greatly increased thereby. Generally the various coils have marked on them the range of wave lengths to which they apply and they may be connected into circuit as needed. The insertion of any coil in circuit may operate a device which sets a pointer on the scale to be used with the given coil. The various condensers are generally thrown into circuit by a switch and their capacities are so chosen that the corresponding wave lengths are a whole number of times smaller or greater than the scale reading. Thus, if the wave lengths on the scale for one condenser are from 150 to 450 meters and the other two condensers are respectively nine times smaller and larger than the one for 150 to 450 meters, it is evident that the wave lengths will be respectively three times ($\sqrt{9}$) smaller and three times ($\sqrt{9}$) larger than the scale value. In this case the condenser switch may have the values of the multipliers, as 1/3, 1, 3, marked on the contact corresponding to the capacity in use.

If on account of the overlapping of two scales, a wave length can be measured on both, it is generally best to use the end of the first scale rather than the beginning of the second, as the accuracy is greater in the former case.

7. Calibration curves.—In some cases where special accuracy is desired, the meter is calibrated by reference to a standard meter, in which the wave lengths are measured for certain points on its scale, as at every 20 degrees, and a curve is plotted with the degrees along the horizontal line, called abscissas, and the wave lengths in

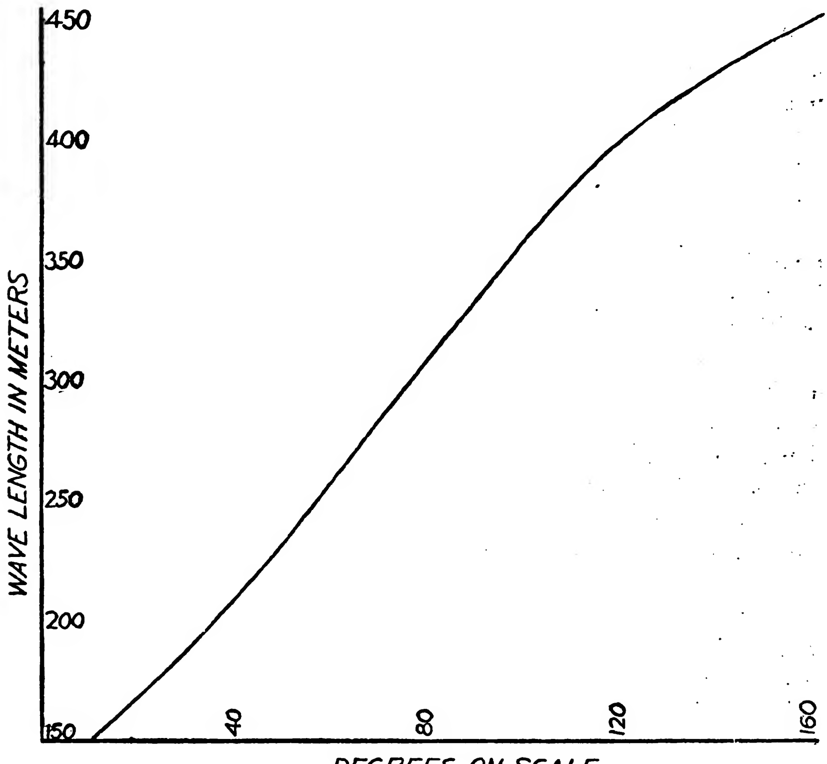

FIG. 2.

meters along the vertical line, called ordinates. The various points are connected by a smooth curve called a calibration curve, so that the wave lengths can be read off for any degree or fraction. Such a curve is shown in figure 2. In special cases meters are calibrated by reference to standard meters by the Bureau of Standards, Washington, D. C. In some meters it is found that there is a slight difference in the calibration curves, depending on whether the meter is used (1) with a buzzer, (2) detector and telephones, or (3) wattmeter. This is due to the small differences in capacity that may

be added when the buzzer, etc., are connected into circuit. In such a case separate calibration curves will be given, each correct for its special use.

Section IV.

CARE OF WAVEMETERS AND DECREMETERS.

8. General care.—There are certain general instructions on the care of wavemeters and decremeters that must be observed. The most important are as follows: A wavemeter and its component parts must be carefully handled; all the component parts must be properly secured in place when not in use or during transportation; and it must be kept in a dry place.

9. Care in handling.—A wavemeter is a delicate instrument which must be handled with great care. Rough handling may break the internal mechanism of the hot-wire ammeter or thermo-galvanometer which is an essential part of a decremeter and of many types of wavemeters; and may injure the windings of the coils and the plates of the condensers. In this respect a wavemeter is more delicate than a receiving set for the following reasons: If either the coil or condenser of a set is slightly changed in any way, the set in general can be retuned to resonance without loss of any of its functions, whereas if the same changes occur in a wavemeter, the values of wave lengths may be seriously changed from those marked on the wave length scales. In meters with a variable air condenser it is the usual practice to provide a device for clamping the moving plates and the *plates should always be so clamped* except when the meter is in actual use. Care must be taken not to drop the telephone receivers or to injure the diaphragm. In the former case the caps may be broken so that the diaphragm can not be held in place. In the latter case the diaphragm may be bent or dented and so touch the pole pieces of the permanent magnets where, if the attraction is strong enough, it may be "frozen" and the telephone made inoperative although otherwise in perfect condition. The telephones should never be taken apart, as it is certain that the adjustments will be disturbed. In explanation it may be stated that in order to get the correct clearance between the diaphragm and the pole pieces, it has been found necessary to grind the latter after the assembly of the telephone, as the standard parts can not be assembled with the necessary accuracy.

10. Care of component parts.—It is absolutely essential that *all* the component parts of a wavemeter, as given in its parts list, be kept with it, as otherwise the meter may be made useless; thus the loss of a coil would make it impossible to measure the wave lengths within its range; the loss of the thermo-galvanometer might make it impossible to obtain measurements at a continuous wave transmitter, etc. For this reason all parts not in actual use should be kept in their proper places in the set box. All types of wavemeters which use a buzzer exciter should have a battery in place in the battery compartment, but the battery *should not be kept there* if the wavemeter is to be stored away, as its deterioration may cause corrosion at the battery contacts and elsewhere. When the wavemeter is to be shipped special care should be taken that (1) the moving plates are clamped; (2) the telephones are stored away according to the following standard practice: Put the two receivers with the faces of the caps together so that all access to the diaphragm is closed; and then bind them together in this position by winding the telephone cord around the outside of the head bands beginning close to the caps; (3) all parts are securely fastened in place; and (4) all parts on the parts list are included.

11. Protection against moisture.—A wavemeter must be kept dry under all conditions. This precaution is particularly necessary in meters having coil forms of wood, whose shape may be greatly changed by exposure to moisture and whose wave lengths would also be changed thereby. If for any reason a wavemeter gets wet, it should be carefully dried out but not by direct exposure to heat.

Section V.

COUPLING AS APPLIED TO WAVEMETERS AND DECREMETERS.

12. Definition of coupling.—In all cases where a wavemeter or a decremeter is used, one of the things that must be done is to bring the wavemeter or decremeter circuit in resonance with another circuit or conversely bring another circuit in resonance with a wavemeter or decremeter circuit. In order to obtain resonance between two circuits, it is necessary to have a transfer of energy between the two. This transfer of energy in all types of wavemeters and decremeters now in use is brought about by inductive coupling. Inductive coupling is obtained by having the magnetic lines of force from one circuit pass through another circuit. In other words, there

is a mutual interlinkage of lines of force. It is these mutual magnetic lines of force which transfer energy between the two circuits. If a large proportion of the lines of force from one circuit interlink with another circuit, the coupling is said to be close. If only a small proportion of the lines of force interlink, the coupling is said to be loose.

13. Effect of coupling on natural wave length of a circuit.—As has been shown, the natural wave length of a circuit depends upon the value of inductance and capacity in that circuit. The value of an inductance in a circuit for any given current depends upon the number of magnetic lines of force passing through the parts of the circuit. The inductance, and hence the natural wave length of a circuit, is changed by a change in the number of lines of force passing through it, such as is brought about by adding the magnetic lines of force from an outside circuit. Thus if an external circuit is coupled to a wavemeter circuit, the latter circuit will have its natural wave length changed. Therefore, in order to make the least possible change in the natural wave length of a wavemeter circuit, the outside circuit should be coupled to it as loosely as possible and yet permit a transfer of energy.

14. How to vary coupling.—Coupling between two circuits may be accurately expressed by the following formula: $\frac{M}{\sqrt{L_1 L_2}}$, where M is the mutual inductance, and L_1 and L_2 are the inductances that are coupled together. It is seen from this formula, therefore, that a variation of M or a variation of the inductances in either or both circuits will change the coupling. The mutual inductance, M, may be varied by a lateral or an angular movement between the two coils which comprise the inductances in question. If the coils are moved closer together, the coupling is made closer or tightened. If the coils are moved apart, the coupling is loosened. Also the coils may be rotated with respect to each other. If the two coils are parallel, the coupling is the tightest. If the two coils are at right angles, the coupling is loosest. In some cases inductance coils have taps on them so that a varying number of turns in the coils may be employed. Changing the number of turns in use changes the inductance and, as has been noted, this changes the coupling between that coil and the circuit with which it may be linked. Of course it is possible to use any combination of these methods in varying the coupling.

It is seen that in order to vary the coupling by moving one coil with respect to another, the position of the coils must be known. In some wavemeters these coils can not be seen, as they are mounted inside the set box. However, in this case, the outside of the set box usually shows by appropriate marking the position of the coil.

15. Tests for correct coupling.—The correct coupling to use is a *loose* coupling. A good method of testing for this proper coupling is as follows: Bring the two circuits in resonance, using what is judged to be a loose coupling. Loosen the coupling by moving one circuit farther away or by any other method, and note whether or not the two circuits remain in resonance. If the two circuits do remain in resonance, the coupling is sufficiently loose. If the two circuits do *not* remain in resonance, continue to loosen the coupling until they do remain in resonance, and then the coupling is sufficiently loose.

SECTION VI.

GENERAL DIRECTIONS FOR USING A WAVEMETER AT A TRANSMITTER.

16. Various uses.—The following instructions apply generally to the uses of a wavemeter at a transmitter of either damped or continuous waves. In later sections explicit instructions will be given for the use of each type of Signal Corps wavemeter. At a transmitter the wavemeter is used as a receiving set to receive the signals at resonance and to measure them from the known electrical constants of its own circuit. It may be used (1) to measure an unknown wave length; (2) to set the transmitter at a predetermined wave length; (3) to calibrate a transmitter in wave lengths; and (4) in some cases to measure the logarithmic decrement of the radiated waves. (See Section XIV.) A careful record should be kept of the adjustments at all measured wave lengths. It must be remembered, however, that in general the antenna circuit adjustments will differ with different antennas, unless it should so happen that they have the same electrical constants.

17. Type of resonance indicator to be used.—Some wavemeters have more than one indicating device, and the one to be used depends in general on the type of the transmitter. If it is a spark set (damped wave), any of the devices mentioned in paragraph 5a may be used—thus, the ear can hear the note of the signals in the telephones of any of the detectors, and the eye can see the movement of the needle of the ammeter, galvanometer, etc. If, however, it is a tube or other continuous wave set, there will be no sound in the telephones unless it is modulated at an audio frequency, and for this reason the ammeter, galvanometer, etc., is used at a tube transmitter.

If a wattmeter or galvanometer is used, care must be taken to use loose coupling not only so as not to change the wave lengths, but also so as not to obtain more than a full scale deflection, otherwise the meter may be burnt out by the excessive current. It is not necessary that the needle of the ammeter or galvanometer be adjusted to zero, as the meter is used to indicate relative and not absolute values. Similarly, if a lamp is used, care must be taken not to burn it at more than normal candlepower.

18. Measuring an unknown wave length.—During these measurements the following general directions are to be observed: (1) The transmitter circuits must be kept *unchanged* at the unknown wave length; (2) the wavemeter coil must be loosely coupled only with the *antenna coil* of the transmitter; and (3) the wavemeter must be tuned to resonance with the transmitter.

If the unknown wave length is approximately known, the wavemeter coil or condenser should be selected which includes this wave length within its range; but if it is entirely unknown, the correct coil, etc., can be found only by trial of the various units. Having chosen the proper indicating device, the wavemeter should then be assembled, taking care that only the necessary connections are made to it—thus, if a wattmeter is to be used, the buzzer and detector circuits must be opened, etc. Next the wavemeter coil should be loosely coupled with the *antenna coil* of the transmitter, and thereafter the coupling between the wavemeter and the transmitter must *remain unchanged.* The wavemeter is then tuned to the transmitter by varying its condenser or variometer slowly over the scale until resonance is obtained, as shown by the maximum response of its indicator. When the two circuits are thus in resonance, the unknown wave length can be read from the wavemeter scale or from the calibration curve.

19. Setting on a predetermined wave length.—During these measurements the following general directions are to be observed: (1) The wavemeter must be set on the predetermined wave length which must *not be changed* thereafter; (2) the wavemeter coil must be loosely coupled with the *antenna coil* of the transmitter; and (3) the transmitter must be tuned to the wavemeter.

The wavemeter coil or condenser should be selected which includes the predetermined wave length within its range and the wavemeter set at this length. Having chosen the proper indicating device, the wavemeter should be assembled, taking care that only the necessary connections are made to it. Next the wavemeter coil should be loosely coupled with the *antenna coil* and the transmitter adjustments varied until resonance with the wavemeter is obtained, as shown by the maximum response of its indicator. When the two circuits are thus in resonance, the transmitter is set at the predetermined wave length.

20. Calibrating a transmitter.—The procedure is the same as outlined in the previous paragraph except that the transmitter is set in succession at a series of predetermined wave lengths, say 100 meters apart, over its range of wave lengths. The various adjustment points are tabulated, or plotted as a calibration curve similar to that in paragraph 7. From this curve a transmitter can be correctly set at any wave length within its range.

21. Wavemeter without a resonance indicator.—At a tube transmitter under certain special circumstances a wavemeter can be used to measure a wave length *without* the use of a resonance indicating device. The method can be applied if there is a sensitive ammeter, (1) in the circuit supplying power to the plate circuits of the vacuum tubes; or (2) in the antenna circuit. In both cases the essential principle is the same, and is as follows: When the wavemeter is loosely coupled to the antenna coil of the transmitter and it is being tuned to the transmitter, or vice versa, there will be a small amount of energy withdrawn from the transmitter by the wavemeter. When the two circuits are *in resonance*, there will be a small but sudden increase in the amount of energy withdrawn. This will be indicated by a corresponding *change* in the reading of either or both ammeters. This method of indicating when the two circuits are in resonance can be used in setting a transmitter at a predetermined wave length and in calibrating a transmitter in addition to the other methods described in this section.

22. Precautions in using a wavemeter at a transmitter.—Referring to paragraph 18 on the precaution of opening the buzzer and detector circuits when the wattmeter is in use, it will be seen from figure 1 that they are connected in shunt to the wavemeter coil and condenser. If either of these circuits is permanently closed, it is evident that both the coil and condenser are short-circuited, and that the meter will probably be made inoperative for this reason.

In coupling the wavemeter coil with the antenna coil, care must be taken that it is coupled *only with this coil*, as it is evident that it is the antenna coil which carries the current of the same wave length as that supplied to the antenna for radiation. This precaution is particularly necessary at a *spark* transmitter where the primary circuit coil may carry a current of a wave length different from that in the antenna.

In applying the method outlined in paragraph 19 to the setting of a *spark* transmitter at a predetermined wave length, it is often difficult to keep the primary and secondary circuits *in resonance* as the transmitter is tuned to the wavemeter. For this reason it may be more convenient to tune the two transmitter circuits to resonance and then to tune the wavemeter to the transmitter. If the measured wave length is not correct, the transmitter circuits should be retuned to resonance

at a slightly longer or shorter wave length, according to the results of the previous measurement, and the wavemeter again tuned to the transmitter. This should be repeated until the wavemeter, when tuned to the transmitter, shows resonance at the predetermined wave length. In the calibration of a *spark* transmitter, it is more convenient to use the method of this paragraph than that of paragraph 20. Although in general the calibration points will not be at a uniform distance apart, yet the calibration curve itself will be the same as in the other method.

Section VII.

GENERAL DIRECTIONS FOR USING A WAVEMETER AT A RECEIVER.

23. Various uses.—The following instructions apply generally to the uses of a wavemeter at a receiver. In later sections explicit instructions will be given for the use of each type of Signal Corps wavemeter. At a receiver the wavemeter is used to generate damped waves of a wave length in meters which is known from the electrical constants of its own circuit. It may be used (1) to measure an unknown wave length; (2) to set a receiver at a predetermined wave length; and (3) to calibrate the receiver circuit in wave lengths.

24. General instructions.—The adjustments of the primary or antenna circuit will differ with different antennas, unless it should so happen that they have the same electrical constants, but the adjustments of the secondary circuit will be practically independent of the antenna.

The adjustments of the following circuits of the receiving set will be known or desired: (1) Antenna and secondary; (2) only the antenna; or (3) only the secondary. In the first two cases the ground and antenna connections should be made and the wavemeter coil loosely coupled with the *antenna circuit coil;* and in the third case the ground and antenna should be disconnected; the antenna circuit coupled as loosely as possible with the secondary so as to avoid any reaction between them; and the wavemeter coil loosely coupled with the *secondary coil.* A careful record should be kept of the adjustments of all measured wave lengths.

25. Measuring an unknown wave length.—During these measurements the following directions are to be observed: (1) The cir-

cuits should be set according to the instructions of the previous paragraph at the same adjustments as when receiving the unknown wave length, and they must be kept *unchanged;* (2) the wavemeter coil must be loosely coupled with the proper coil in the receiving circuit; (3) the wavemeter caused to generate oscillations; and (4) the wavemeter tuned to resonance with the receiving set, as shown by the telephones of the latter circuit.

If the unknown wave length is approximately known, the wavemeter coil or condenser should be selected which includes this wave length within its range; but if it is entirely unknown, the correct coil, etc., can be found only by trial of the various units. The wavemeter should be assembled and the buzzer connected into circuit. Care must be taken that only the necessary connections are made to the wavemeter—thus, the detector circuit must be opened, etc. Next the buzzer should be started and the wavemeter tuned to the receiver by slowly varying its condenser or variometer over the scale until the loudest signals are heard in the telephones of the receiving set. The wavemeter is then in resonance with the receiver at the unknown wave length, which can be read from the wavemeter scale or calibration curve.

26. Setting at a predetermined wave length.—During these measurements the following general directions are to be observed: (1) The wavemeter should be set at the predetermined wave length, which must *not be changed* thereafter; (2) the wavemeter coil must be loosely coupled with the proper coil in the receiving circuit; (3) the wavemeter caused to generate oscillations; and (4) the receiver tuned to resonance with the wavemeter, as shown by the telephones of the receiver circuit.

The wavemeter coil or condenser should be selected which includes the predetermined wave length within its range and the wavemeter set at this wave length. The wavemeter should be assembled and the buzzer connected into circuit. Care must be taken that only the necessary connections are made to the wavemeter—thus, the detector circuit must be opened, etc. Next the buzzer should be started and the receiving circuits tuned to the wavemeter, as though it were a distant station, until the loudest signals are heard in the telephones of the receiving set. The receiving circuits are then in resonance with the wavemeter at the predetermined wave length.

27. Calibrating a receiver.—The procedure is the same as that outlined in the previous paragraph except that the wavemeter is set in succession at a series of predetermined wave lengths over its range of wave lengths. The various adjustment points are tabulated or plotted as a calibration curve similar to that described in paragraph 7. From this curve a receiver can be correctly set at any wave length within its range.

Inasmuch as the secondary circuit wave lengths are independent of the antenna, it is the general practice to mark the wave lengths only on the scales of this circuit. If, however, the primary values are known, even for a temporary antenna, they should be tabulated as they will permit of a quicker use of the set on all its wave lengths.

28. Wavemeter without a resonance indicator.—At a receiver, under certain special conditions a wavemeter can be used to measure a wave length *without* the use of the buzzer or other auxiliary device. The method is similar in principle to that described in paragraph 21, and can be applied if the receiver is provided with an oscillating tube detector or "autodyne." When the wavemeter is loosely coupled with the proper receiving circuit coil and it is being tuned to the receiver, or vice versa, a small amount of energy is withdrawn from the receiving circuits by the wavemeter. When the two circuits are *in resonance* there will be a small but sudden increase in the amount of energy withdrawn and a corresponding *change* in the current in the telephones of the receiving set. This will be indicated by a "click" in the telephones. This method can be used in setting a receiver at a predetermined wave length and in calibrating a receiver in addition to the methods described in this section.

29. Precautions in using wavemeter at a receiver.—In almost all cases only a single dry cell is needed to operate the buzzer, and if, with the cell in circuit, the buzzer can not be operated, the cell should be replaced. No more batteries should be used than are needed for the operation of the buzzer, as additional batteries tend to cause an arc at the buzzer contacts, which may prevent the generation of any oscillations. This is similar to the case of a spark transmitter where an arc instead of a spark is produced at the gap when the voltage of the transformer is excessive.

Section VIII.

MEASUREMENT OF INDUCTANCE OR CAPACITY BY THE USE OF A WAVEMETER OR DECREMETER.

30. Measurement of inductance or capacity.—As stated previously, a wavemeter or a decremeter can be used with other apparatus to measure an inductance or a capacity. If a local resonant circuit containing either a known inductance and an unknown capacity, or an unknown inductance and a known capacity, is set into oscillation by any convenient means, such as a buzzer, small spark coil, tube oscillator, etc., then according to paragraph 3—

$$\lambda = 59{,}600 \times \sqrt{LC} \text{ meters.}$$

If now the wave length of the local circuit be measured by a wavemeter or a decremeter, then all but one of the quantities in the formula are known, and the unknown inductance or capacity can be found from either of the two following formulas which are derived by simple algebra from the formula above:

$$L = \frac{\lambda^2}{3.56 \times 10^9 \times C}$$

$$C = \frac{\lambda^2}{3.56 \times 10^9 \times L}$$

where as before L is the inductance in milli-henrys,
C is the capacity in microfarads,
λ is the wave length in meters.

SECTION IX.

WAVEMETER; TYPE SCR-60-C.

31. Use and range of wave lengths.—This wavemeter can be used at either a damped or a continuous wave transmitter, and at a receiver, for all purposes except the measurement of the logarithmic decrement of a transmitter. Its range of wave lengths is from 75 to 2,000 meters.

32. Description of meter.—The meter is of the type that uses a set of coils for the inductance; and a variable air condenser for the capacity. It is provided with a hot wire galvanometer; with a crystal detector but *no* telephones; and with battery and buzzer, etc. All parts are mounted on a panel, and are contained in a box with a removable cover. The top view is shown in figure 3, and the interior in figure 4. The over-all dimensions are approximately 9½ by 9 by 8 inches high, including the carrying handle. Its weight is about 7 pounds.

33. Component parts.—There are three *coils* permanently mounted on the underside of the panel and connected in series. A three-way rotary switch in the upper center of the panel makes the connections at numbered contacts, as follows: (1) Short-circuits

two of the coils, leaving the third coil in circuit for the shortest wave lengths; (2) short-circuits one coil, leaving the two others in circuit in series for the medium wave lengths; and (3) removes the short circuits and leaves all three coils in series for the longest wave lengths. The three scales of wave lengths corresponding to the three positions of the switch are marked on the dial of the variable condenser and are as follows: (1) 75 to 200 meters; (2) 200 to 550 meters; and (3) 550 to 2,000 meters. The coils are in the right end of the set box or wavemeter and the plane of the windings is parallel to the front and rear of the box, although not indicated by an arrow as is usually the case.

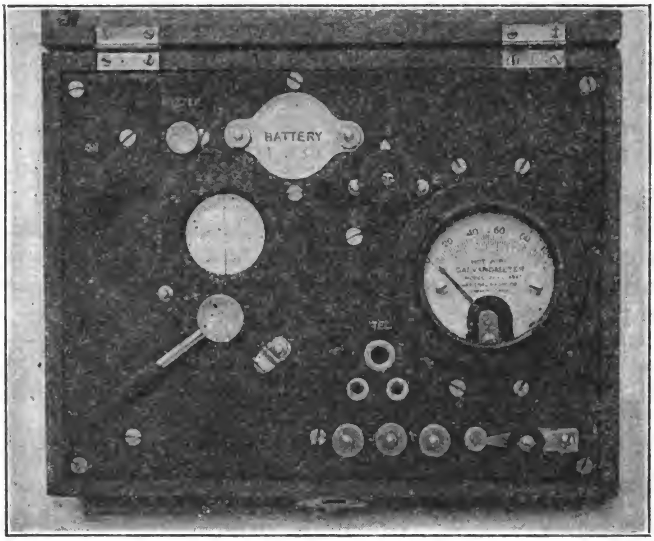

FIG. 3.

The *condenser* is a variable air condenser of the usual type. The handle at the left of the panel carries the wave length scales on a depressed dial that is read through a circular opening in the panel just above the condenser handle. The moving plates can be clamped by turning the handle to its extreme position, where it is locked in place by a spring catch.

The meter is provided with two means of indicating resonance: (1) A *hot wire galvanometer;* and (2) a *crystal detector.*

The galvanometer is connected in series in the circuit and is not shunted by a resistance. It is provided with a zero adjusting screw.

The *detector* is a galena crystal (lead sulphide) in light contact with a metal point on a flat spring which is adjustable as to pressure by means of a screw. It may be put into circuit in either of two types of connections, depending on the manner in which the tele-

phones are connected: (1) In series with the telephones across the condenser; or (2) in the "unipolar" connection to one terminal of the condenser.

The *telephones*, which must be supplied from outside sources, should be of the high impedance type, and may be provided with (1) ordinary tip terminals; (2) standard plug, type PL–5, as in the standard head sets, type P–11; or (3) standard plug type PL–7, as in the standard head sets, type HS–2. In the first case two different connections can be made depending on which two of the three binding posts at the lower edge of the panel are used. If the telephones are

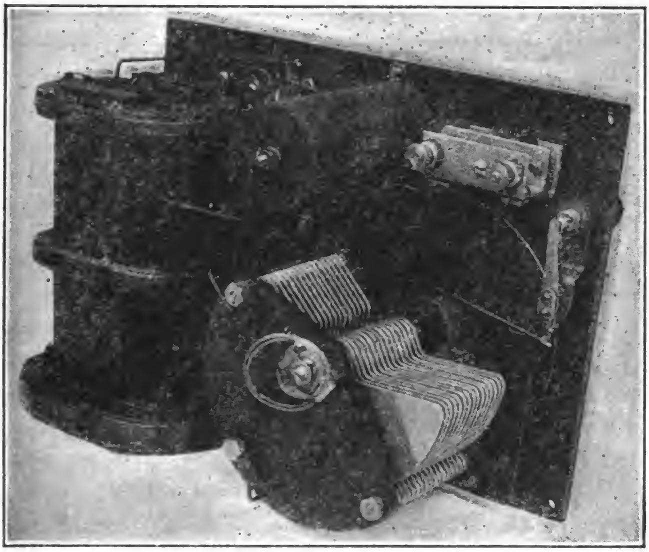

FIG. 4.

connected to the two posts between which the letter "D" is stamped, the detector and telephones are in series across the condenser terminals. If they are connected to the two posts between which the letter "U" is stamped, the detector and telephones are in the unipolar connection. If either of the standard plugs is used, the telephones are in series with the detector across the condenser.

The buzzer exciting circuit comprises the buzzer, battery, and switch, which is connected to the terminals of the condenser as shown in the schematic wiring diagram in figure 5, with the circuit completed through the three inductance coils. The *buzzer* is mounted on the underside of the panel with an adjustment screw for the vibrator projecting through the panel in the left corner and marked "Buzzer." It is driven by a single dry cell *battery*, that is contained in the com-

partment at the top of the panel marked "Battery." The *buzzer switch* is the button at the left edge of the panel and is closed when the arrow on the button is pointing to "On" and open when pointing away. The schematic wiring diagram of the wavemeter is shown in figure 5.

34. General instructions.—Before making any measures with the wavemeter, reference should be made to Sections IV, V, VI and VII for the various points which must be observed in the care of meters and in their use at a transmitter and at a receiver. When the meter is not in use, or is to be stored away, or made ready for transportation, the condenser plates should be clamped by the spring catch.

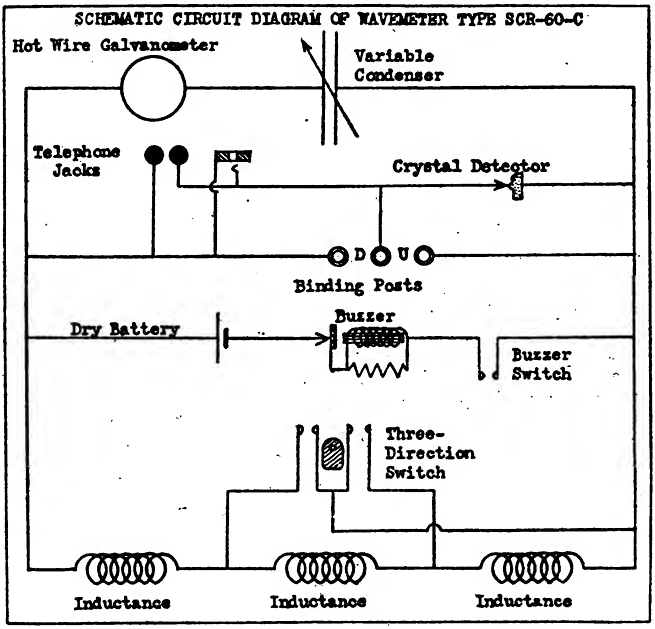

FIG. 5.

35. Measuring an unknown wave length at a transmitter.—Set the three-way switch on the scale that includes within its range the wave length to be measured; unclamp the condenser plates; disconnect the telephones; open-circuit the detector; and set the buzzer switch in the "Off" position. Make no other connections on the meter. Loosely couple the wavemeter coils with the *antenna coil* of the transmitter; and turn the condenser handle slowly over its scale until a maximum reading is obtained on the galvanometer, thus indicating that the wavemeter is in resonance with the transmitter. Read the wave length in meters on the scale corresponding to the position in which the three-way switch is set.

At a *damped wave* (spark) transmitter when the detector and telephones are to be used, the following directions are to be followed: Set the three-way switch on the scale that includes within its range the wave length to be measured; set the buzzer switch in the "Off" position; and plug the telephones in the jacks or connect them to the binding posts as the case may be—for present purposes there is no essential difference between the two types of connections. Make no other connections on the meter. Loosely couple the wavemeter coils with the *antenna coil;* and adjust the detector to a sensitive point. Turn the condenser handle slowly over its scale until the loudest signals are heard in the telephones, thus indicating that the wavemeter is in resonance with the transmitter, etc., as above.

36. Setting a transmitter at a predetermined wave length.—Set the three-way switch on the scale that includes the predetermined wave length, and the condenser at the wave length; set the buzzer switch at the "Off" position; connect in the galvanometer or the detector and telephones; and do not change the wavemeter adjustments thereafter. Loosely couple the wavemeter coils with the *antenna coil* and tune the transmitter to the wavemeter until the galvanometer or telephones show by the maximum response that the two circuits are in resonance at the predetermined wave length. At a *spark transmitter* it may be more convenient to tune the wavemeter to the transmitter, as described in paragraph 22.

37. Calibrating a transmitter.—The procedure is the same as in the previous paragraph, except that the transmitter is set in succession at a series of predetermined wave lengths, etc., as described in paragraphs 19 and 20.

38. Measuring an unknown wave length at a receiver.—Set the three-way switch on the scale that includes within its range the wave length to be measured; disconnect the telephones; and open-circuit the detector. Be sure that there is a battery in circuit in the battery compartment, and then turn on the buzzer switch, adjusting the vibrator by the screw at "Buzzer," if necessary, until the buzzer gives a clear, steady note. Loosely couple the wavemeter coil with the proper receiving circuit coil, as described in paragraph 24. Turn the condenser handle of the wavemeter slowly over its scale until the loudest signals are heard in the telephones of the receiving set, thus indicating that the receiver circuits are in resonance with the wavemeter at the unknown wave length. Read the wave length in meters on the scale in use.

39. Setting a receiver at a predetermined wave length.—Set the three-way switch on the scale that includes the predetermined wave length, and the condenser on the wave length; disconnect the telephones; open-circuit the detector; turn on the buzzer switch;

and do not change the wavemeter adjustments thereafter. Loosely couple the wavemeter with the proper receiving circuit coil, as described in paragraph 24, and tune the receiver circuits to the wavemeter, as though it were a distant station, until the telephones of the receiver indicate by the loudest signals that the circuits are in resonance with the wavemeter at the predetermined wave length.

40. Calibrating a receiver.—The procedure is the same as in the previous paragraph except that the wavemeter is set in succession at a series of predetermined wave lengths, etc., as described in paragraph 27.

Section X.

WAVEMETER; TYPE SCR-61.

41. Use and range of wave lengths.—This wavemeter can be used at a damped wave transmitter and at a receiver for all purposes, except the measurement of the logarithmic decrement of a transmitter. If provided with an external "current squared" meter or an ammeter, it can be used at a continuous wave transmitter. Its range of wave lengths is from 150 to 2,600 meters.

42. Description of meter.—The meter is of the type that uses a set of coils for the inductance and a variable air condenser for the capacity. It is provided with a crystal detector and telephones; and with a battery and buzzer, etc. There are also provided binding posts for connection to an external vacuum tube detector, and galvanometer or ammeter. Most of the parts are mounted on a panel and the rest carried in compartments. The meter is self-contained in a box with hinged cover and a carrying strap. It is shown assembled and ready for use in figure 6. The over-all dimensions are approximately 15½ by 9 by 11 inches high, including the carrying strap. Its weight is about 23 pounds.

43. Component parts.—Three *coils* are provided, wound on mahogany forms with the windings protected by insulating covers. Each coil is marked with a letter and its inductance in milli-henrys as follows: "A" 0.052 M. H.· "B" 0.319 M. H.; and "C" 1.715

M. H. Three scales of wave lengths, "A," "B," and "C," are marked on the dial at the variable condenser to correspond with the three coils and their ranges are as follows: "A," from 150 to 500 meters; "B," from 400 to 1,200 meters; and "C," from 800 to 2,600 meters. There is also provided a scale of degrees from 0 to 180 so that a calibration curve can be made for each coil if desired. A coil is connected into circuit by placing it in the left end of the cover of the box with the lettered side uppermost and toward the top of the cover. Two centering pins, a large one at the left and a small one at the right, fit into corresponding holes in the brass strip across the center of the coil, and automatically permit only the correct placing of the coil in circuit. It should be fastened in

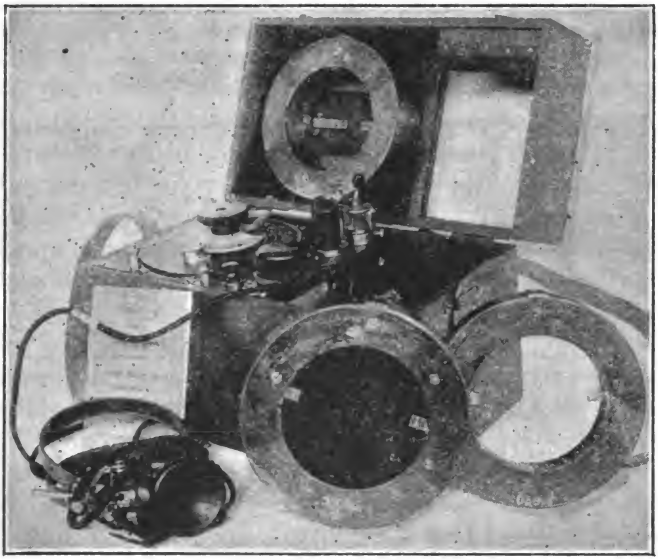

FIG. 6.

place by giving the winged thumb nut one-quarter of a turn. In this position the terminals of the coil at the two small brass plates on the underside of the wood form are connected to the two spring contacts in the cover and thence by flexible leads to the air condenser.

The *condenser* is a variable air condenser of the mechanically balanced type with two sets of fixed and moving plates. The moving plates can be clamped in place by the nut close to the condenser handle either to keep the meter at a constant wave length when desired or to secure the plates in place during transportation. One set of the fixed plates is grounded on the metal lining of the condenser compartment.

The *detector* is a galena crystal (lead sulphide) in light contact with a brass wire, and is inclosed to keep it dry and clean. The

crystal is held in place by a screw on the outside of the detector stand, and the contact wire is adjustable by a ball and socket joint, the pressure on which is controlled by the nut on top of the brass post close to the stand. If desired, a *vacuum tube detector* can be used instead of the crystal detector by making suitable connections to the "Grid" and "Fil" binding posts on the front edge of the panel.

Similarly an external *ammeter* or *thermo-galvanometer* may be used instead of the detector by making suitable connections to the "Meter" binding posts in the upper left corner of the panel which ordinarily are short-circuited by a wide strip of brass. Except when the ammeter, etc., is in use, care must be taken to see that the strip makes good connections as it is in series in the wavemeter circuit.

The *telephones* are of the high impedance type adapted for use either with a crystal or vacuum tube detector. They may be provided

SCHEMATIC DIAGRAM FOR SCR-61

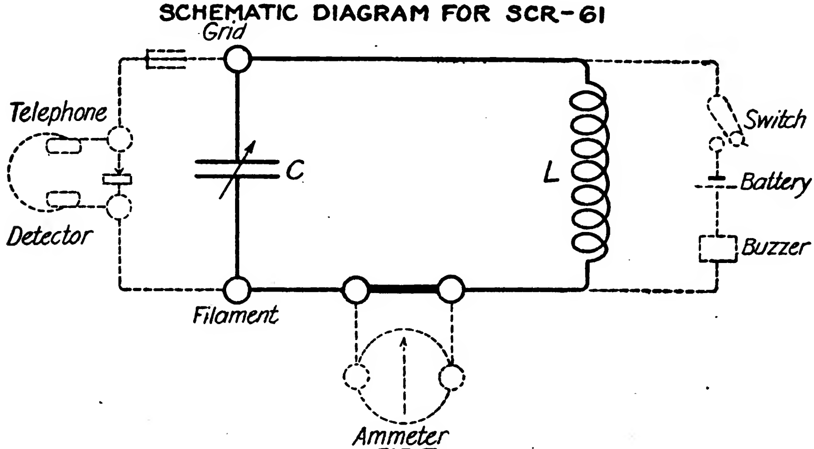

FIG. 7.

with either the standard plug, type PL–5, as in the standard head sets, type P–11, or with tip terminals. In the former case, they should be plugged into the jack just in front of the detector stand and in the latter case they may be connected to the "Grid" and "Fil" binding posts. The connections are the same in both cases, being directly in shunt to the detector, one terminal of which is connected through the metal lining of the box to one side of the variable condenser, and the other terminal through a very small condenser to the other side of the variable condenser. This differs slightly from the usual detector connection which puts the telephones in shunt to a condenser and not a detector. These connections are as shown schematically in figure 7 except that the "Grid" post is at the common terminal of the telephone and detector.

The buzzer exciting circuit comprises the buzzer, battery, and switch, which is connected to the terminals of the condenser with

the circuit completed through the metal lining of the box and the inductance coil in circuit. The *buzzer* is mounted on the top side of the panel and is driven by a single dry cell *battery* that is held in spring clips on the underside of the panel just below the buzzer. Access to the battery for its renewal, etc., is through a hinged door opening out into the right-hand compartment of the box. The buzzer *switch* is the black push button on the front edge of the panel, which is in the "Off" position when pulled up and in the "On" position when pushed down.

As the metal lining of the box is used as a part of both the detector and buzzer circuits and as contact is made under three of the four machine screws in the corners of the panel, all of the screws should be kept screwed into place, otherwise the meter may be inoperative both at a receiver and at a transmitter.

44. General instructions.—Before making any measurements with the wavemeter, reference should be made to Sections IV, V, VI, and VII for the various points which must be observed in the care of meters and in their use at a transmitter and at a receiver. When the meter is not in use, or is to be stored away, or made ready for transportation, the three coils should be put in the right-hand compartment; the *condenser plates clamped;* the telephones secured as in paragraph 10, and placed centrally on top of the condenser with the caps between the buzzer and the detector stand; and the cover securely fastened in place.

45. Measuring an unknown wave length at a transmitter.—Connect the coil into circuit, which includes within its range the wave length to be measured; unclamp the condenser plates; and pull up the buzzer switch to its "Off" position. Be sure that the two "Meter" binding posts are firmly short-circuited by the strip of brass. Plug in the telephones and make no other connections to the meter. Loosely couple the wavemeter coil with the *antenna coil* of the transmitter and adjust the detector to a sensitive point. Turn the condenser handle slowly over its scale until the loudest signals are heard in the telephones, thus indicating that the wavemeter is in resonance with the transmitter. Read the wave length in meters on the scale corresponding to the coil in use.

45a. Use of external vacuum tube detector.—If such a detector—which is assumed to be complete and operative—is to be used, instead of the crystal detector, the following directions are to be observed: Open-circuit the detector; remove the telephones; connect the grid and the filament of the tube set respectively to the "Grid" and "Filament" binding posts; make no other connections to the wavemeter; and use the telephones of the tube set. Loosely couple the wavemeter and proceed as in the previous paragraph.

45b. Use of external galvanometer.—If such a detector is to be used, the following directions are to be observed: Connect the coil

into circuit which includes within its range the wave length to be measured; pull up the buzzer switch to its "Off" position; open-circuit the detector; remove the telephones; and open the short-circuiting strip at the "Meter" binding posts. Connect the galvanometer into circuit at these posts, being sure to use the shortest possible leads in order to avoid adding inductance into circuit, and thus changing the computed values on the wave-length scales. Make no other connections to the wavemeter. Loosely couple the wavemeter coil with the *antenna coil* of the transmitter; turn the condenser handle slowly over its scale until a maximum reading, etc., similar to above.

46. Setting a transmitter at a predetermined wave length.—Connect the coil into circuit which includes within its range the predetermined wave length; set the condenser at the wave length; pull up the buzzer switch to its "Off" position; connect in the galvanometer or detector and telephones; and do not change the wavemeter adjustments thereafter. Loosely couple the wavemeter coil with the *antenna coil* and tune the transmitter to the wavemeter until the galvanometer or telephones show by the maximum response that the two circuits are in resonance at the predetermined wave length. At a *spark* transmitter it may be more convenient to tune the wavemeter to the transmitter as described in paragraph 22.

47. Calibrating a transmitter.—The procedure is the same as in the previous paragraph, except that the transmitter is set in succession at a series of predetermined wave lengths, etc., as described in paragraphs 19 and 20.

48. Measuring an unknown wave length at a receiver.—Connect the coil into circuit which includes within its range the wave length to be measured; disconnect the telephones; and open-circuit the detector. Be sure that there is a battery in circuit and then push down the buzzer switch to its "On" position, adjusting the vibrator if necessary until the buzzer gives a clear, steady note. Loosely couple the wavemeter coil with the proper receiving circuit coil, as described in paragraph 24. Turn the condenser handle of the wavemeter slowly over its scale until the loudest signals are heard in the telephones of the receiving set, thus indicating that the receiving circuits are in resonance with the wavemeter at the unknown wave length. Read the wave length in meters on the scale in use.

49. Setting a receiver at a predetermined wave length.—Connect the coil into circuit which includes within its range the predetermined wave length; set the condenser at this wave length; disconnect the telephones; open-circuit the detector; pull up the buzzer switch; and do not change the wavemeter adjustments thereafter. Loosely couple the wavemeter with the proper receiving

circuit coil, as described in paragraph 24, and tune the receiver circuits to the wavemeter as though it were a distant station, until the telephones of the receiver indicate by the loudest signals that the circuits are in resonance with the wavemeter at the predetermined wave length.

50. Calibrating a receiver.—The procedure is the same as in the previous paragraph except that the wavemeter is set in succession at a series of predetermined wave lengths, etc., as described in paragraph 27.

SECTION XI.

WAVEMETERS—TYPES SCR-95, SCR-111, SCR-125, SCR-125-A, AND SCR-128.

51. Use and range of wave lengths.—These meters are all of the same general type, differing principally in the range of wave lengths and in minor details of construction. They can be used at either a *damped* or a *continuous wave* transmitter and at a receiver for all purposes, except that they can not be used to measure the logarithmic decrement of a transmitter. The ranges of wave lengths for the different meters are given here for the sake of convenient reference:

SCR-95	500 to 1,100 meters.
SCR-111	900 to 1,900 meters.
SCR-125	70 to 560 meters.
SCR-125-A	70 to 560 meters.
SCR-128	50 to 75 meters.

52. Description of meters.—The meters are of the type that use a variometer for the inductance and one or more fixed condensers for the capacity. They are provided with a miniature lamp with rheostat for indicating resonance; a buzzer and battery, etc. All parts are mounted on a panel which can be removed from the set box, and the meter is self-contained. Instructions and a wiring diagram for

each type of meter are contained on the inside of its set box cover. A top view of the SCR–95 is shown in figure 8, and an inside view in figure 9. The over-all dimensions of the various meters differ slightly, but do not exceed 5 by $5\frac{1}{2}$ by 5 inches high. The weight is about 4 pounds.

53. Component parts.—The *variometer* is mounted on the underside of the panel and is of the type described in paragraph 4b, wound with enamel wire on two forms or frames of an insulating material known as bakelite. The rotation of the inner coil changes the in-

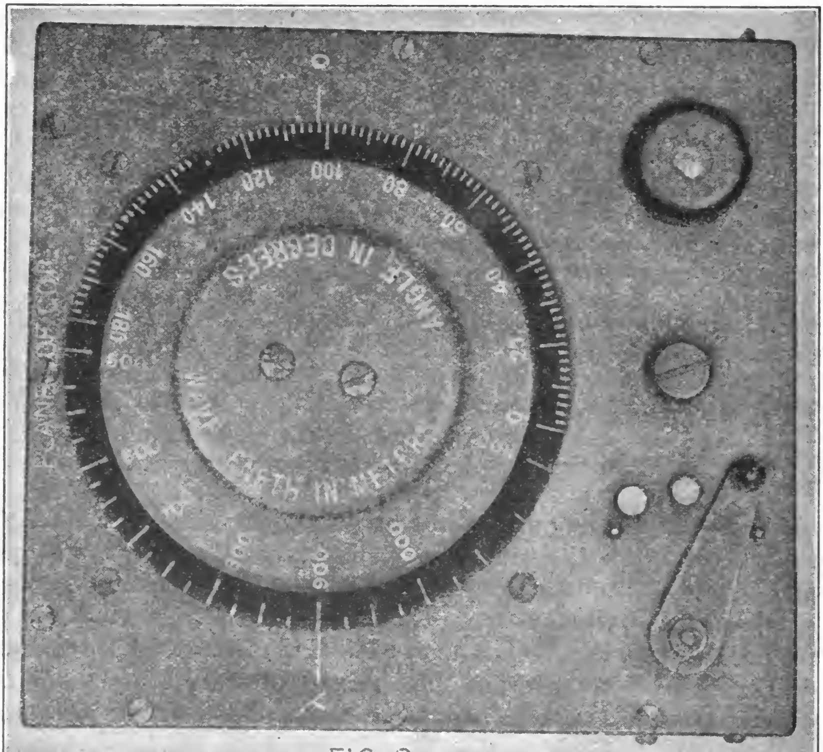

FIG. 8.

ductance in circuit and hence the wave length, and its shaft carries the dial and the wave length scale. The maximum value of the inductance is between 4 and 9 times larger than the minimum value, so that the longest wave length on the scale is between 2 ($\sqrt{4}$) and 3 ($\sqrt{9}$) times longer than the shortest wave length. The "Plane of coil" is indicated by an arrow on top of the meter, and in this case refers to the plane of the larger and fixed variometer coil.

The *condenser* is mounted on the underside of the panel and is of mica, sealed in a waterproof compound to exclude air and moisture.

In some meters three condensers are provided which can be connected into circuit by a *condenser* or *wave length* "*multiplier*" *switch* so as to give three ranges of wave lengths. In this case the capacities are in the ratio of either 1, 4, and 16; or 1, 9, and 81, so that the wave lengths will be as 1, 2, and 4; or 1, 3, and 9. Thus a single direct reading scale of wave lengths may be used, which as the different condensers are put into circuit by the switches, should be multiplied by the corresponding numbers 1, 2, and 4, etc., to give the other wave lengths.

The *miniature lamp* is mounted on top of the panel with a screw base and is protected by a hood which is removable for the renewal of the lamp by rotating it a fraction of a turn. It is permanently

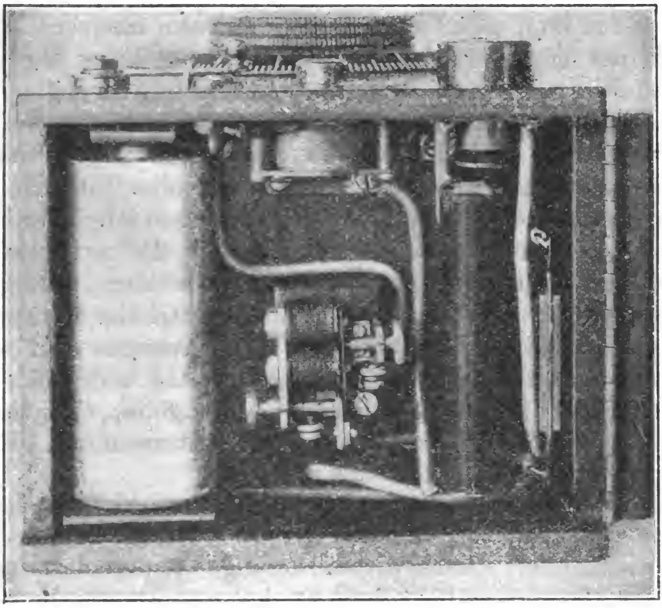

FIG. 9.

connected in circuit in series with the variometer and condenser. The lamp filament is most sensitive in showing any small increase in current when it is lighted to a dull red glow. For this reason the buzzer battery and an adjustable resistance are connected in series across the lamp terminals at the "C" contact at the three-way switch, so that the filament can be brought to its sensitive point. The *resistance* consists of a pile of carbon plates on the underside of the panel, which is adjustable by means of a screw on top of the panel marked "Lamp resistance." A *choke coil* of enamel wire is mounted on the underside of the panel in the front compartment and is used in the lamp and battery circuit to prevent the high frequency oscillations from flowing through that circuit instead of

through the lamp. Although the battery is disconnected at the "A" contact of the three-way switch so that the filament is not lighted thereby, yet it is to be noted that the wavemeter is still operative as its circuit is still complete and the filament *may* be lighted at resonance by *strong* signals.

The *buzzer* is connected in circuit at the "B" contact of the three-way switch and is driven by a single dry cell battery that is held in place by spring clips in the front compartment of the set box. The *battery* is cut out of circuit at the "A" or "Off" position of the three-way switch.

54. General instructions.—Before making any measures with the wavemeter, reference should be made to Sections IV, V, VI, and VII, for the various points which must be observed in the care of meters and in their use at a transmitter and at a receiver. When the meter is not in use the battery switch should be at the "A" or "Off" position, and when stored away, the battery should be removed from its compartment.

55. Measuring an unknown wave length at a transmitter.—If there is a condenser or wave length "Multiplier" switch, set it on the scale that includes within its range the wave length to be measured; be sure there is a battery in circuit in the battery clips; set the battery switch on the "C" or "On" position; and adjust the "Lamp resistance" by means of its screw until the filament burns at a dull red glow. Loosely couple the wavemeter coil with the *antenna coil* of the transmitter; and turn the variometer handle slowly over its scale until the lamp glows brightest, thus indicating that the wavemeter is in resonance with the transmitter. Read the wave length in meters on the scale in use.

56. Setting a transmitter at a predetermined wave length.—If there is a condenser or wave length "Multiplier" switch, set it on the scale that includes within its range the predetermined wave length; set the variometer handle at the wave length; be sure that there is a battery in circuit in the battery clips; set the battery switch at the "C" position; adjust the "Lamp resistance" by means of its screw until the filament burns at a dull red glow; and do not change the wavemeter adjustments thereafter. Loosely couple the wavemeter coil with the *antenna coil* and tune the transmitter to the wavemeter until the lamp shows by its brightest glow that the two circuits are in resonance at the predetermined wave length.

At a *spark* transmitter it may be more convenient to tune the wavemeter to the transmitter, as described in paragraph 22.

57. Calibrating a transmitter.—The procedure is the same as in the previous paragraph, except that the transmitter is set in succession at a series of predetermined wave lengths, etc., as described in paragraphs 19 and 20.

58. Measuring an unknown wave length at a receiver.—If there is a condenser or wave length "Multiplier" switch, set it on the scale that includes within its range the wave length to be measured; be sure that there is a battery in circuit at the battery clips; set the battery switch on the "B" contact, adjusting the buzzer if necessary until it gives a clear, steady note. Loosely couple the wavemeter coil with the proper receiving circuit coil as described in paragraph 24. Turn the variometer handle slowly over its scale until the loudest signals are heard in the telephones of the receiving set, thus indicating that the receiver circuits are in resonance with the wavemeter at the unknown wave length. Read the wave length in meters on the scale in use.

59. Setting a receiver at a predetermined wave length.—If there is a condenser or wave length "Multiplier" switch, set it on the scale that includes the predetermined wave length; set the variometer handle at the wave length; set the battery switch on the "B" contact, adjusting the buzzer if necessary until it gives a clear, steady note; and do not change the wavemeter adjustments thereafter. Loosely couple the wavemeter coil with the proper receiving circuit coil, as described in paragraph 24; and tune the receiver circuits to the wavemeter as though it were a distant station, until the telephones of the receiver indicate by the loudest signals that the circuits are in resonance with the wavemeter at the predetermined wave length.

60. Calibrating a receiver.—The procedure is the same as in the previous paragraph except that the wavemeter is set in succession at a series of predetermined wave lengths, etc., as described in paragraph 27.

61. The SCR–95.—This is a *single-scale* wavemeter, with a range of wave lengths from 500 to 1,100 meters. As can be seen from the wiring diagram in figure 10, the 3-point battery switch has contacts as follows: "A" to disconnect the battery; "B" to connect the battery to the buzzer; and "C" to connect the battery to the lamp. The "Plane of coil" is parallel to the back of the set box. The following brief instructions are contained on the inside of the set-box cover:

To measure wave length, set switch on "C" and adjust carbon resistance until lamp glows a dull red. Couple wavemeter by holding near inductance coil of sending set. Rotate dial slowly until lamp lights to maximum brilliancy, when wave length is indicated on wavemeter dial.

To set receiver for given wave length, set switch on "B," adjust buzzer to give a clear note, and turn dial to desired wave length. Couple as above, and tune receiver until buzzer is heard loudest in phones.

CAUTION.—Replace battery when it fails to operate buzzer or lamp. When meter is not in use leave switch on "A" only.

62. The SCR–111.—This is a *single-scale* meter, with a range of wave lengths from 900 to 1,900 meters, almost identical with the

SCR–95 except for the wave lengths. The wiring diagram is identically the same as in the SCR–95 (fig. 10). The 3-point battery switch has contacts as follows: "A" to disconnect the battery; "B" to connect the battery to the buzzer; and "C" to connect the battery to the lamp. The "Plane of coil" is parallel to the back of the set box. The following brief instructions are contained on the inside of the set-box cover:

To measure wave length, set switch on "C" and adjust carbon resistance until lamp glows a dull red. Couple wavemeter by holding near inductance coil

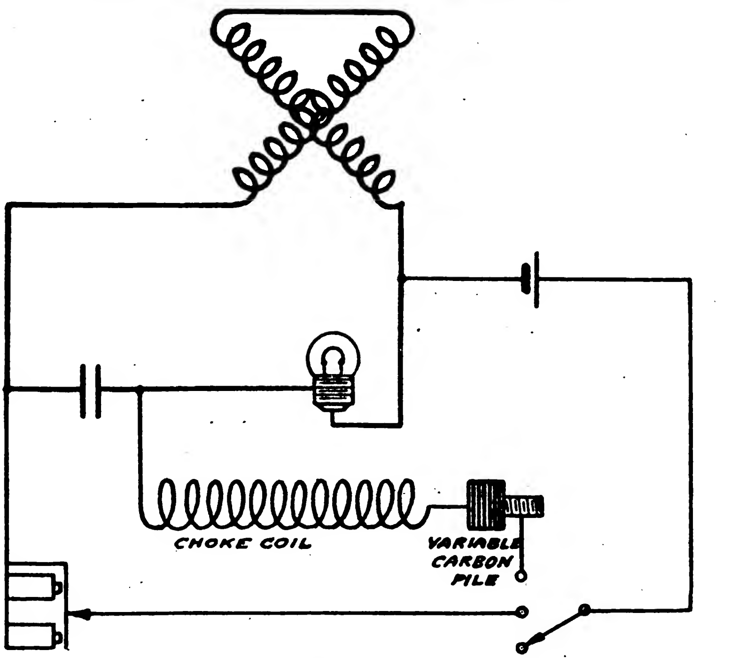

FIG. 10.

of sending set. Rotate dial slowly until lamp lights to maximum brilliancy, when wave length is indicated on wavemeter dial.

To set receiver for given wave length, set switch on "B," adjust buzzer to give a clear note, and turn dial to desired wave length. Couple as above, and tune receiver until buzzer is heard loudest in phones.

Caution.—Replace battery when it fails to operate buzzer or lamp. When meter is not in use leave switch on "A" only.

63. The SCR–125.—This is a *3-scale* meter with a range of wave lengths from 70 to 560 meters. It is direct reading from 70 to 140 meters, and as the multipliers are 1, 2, and 4, the scale also reads from 140 to 280 meters, and from 280 to 560 meters. As can be

seen from the wiring diagram in figure 11, the 3-point switch has contacts as follows: "A" to disconnect the battery; "B" to connect the battery to the buzzer; and "C" to connect the battery to the lamp. The "Plane of coil" is parallel to the back of the set box. The following brief instructions are contained on the inside of the set box cover:

This instrument has three wave length ranges obtained by three values of capacity. With the condenser switch on position 1, the wave length range is approximately 70 to 140 meters, the wave length dial reads directly in meters. With the condenser switch on position 2, the wave lengths indicated

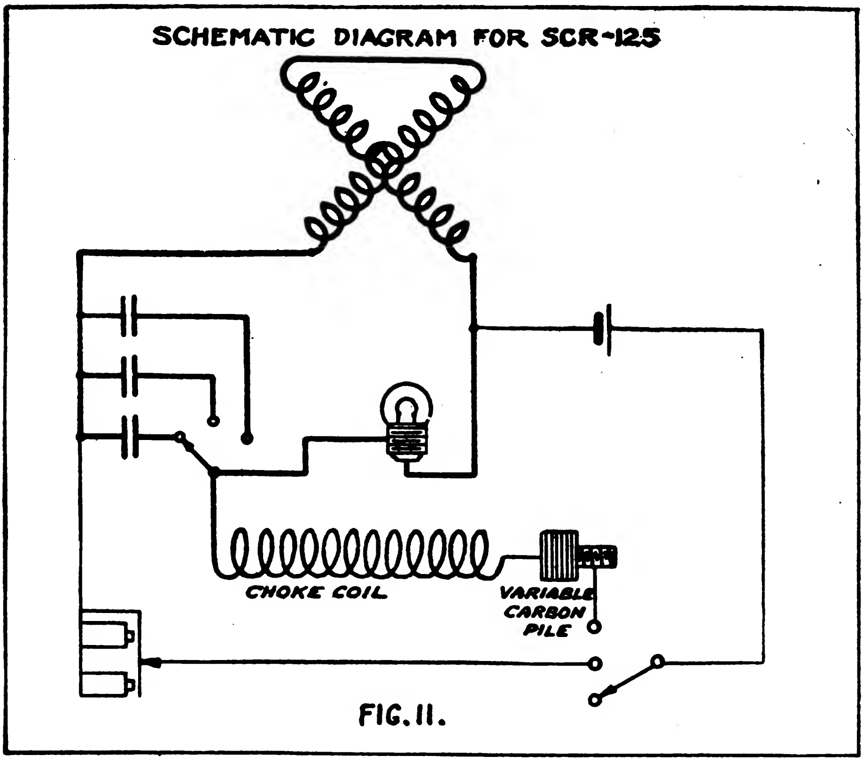

FIG. 11.

on the dial must be multiplied by 2, and correspondingly with the condenser switch on position 4, the dial reading must be multiplied by 4.

To measure wave length, set circuit switch on "C," and adjust carbon resistance until the lamp glows a dull red. Couple the wavemeter by holding it near the inductance coil of the sending set. Rotate the dial slowly until the lamp shows maximum brilliance, the wave length will then be indicated on the wavemeter dial.

To set the receiver for a given wave length, set the "circuit switch" on "B." Adjust the buzzer to give a clear note, and turn the dial to the desired wave length. Couple as above and tune the receiver until the buzzer is heard loudest in the telephone receivers.

Caution.—Leave circuit switch in "A" position when the wavemeter is not in use.

64. The SCR–125–A.—This is a *3-scale* meter, very similar to the SCR–125, with a range of wave lengths from 50 to 1,350 meters. It is direct reading from 150 to 450 meters, and as the multipliers are 1/3, 1, and 3 the scale reads also from 50 to 150 meters, and from 450 to 1,350 meters. As can be seen from the wiring diagram in figure 12, the 3-point switch has contacts as follows: "A" to disconnect the battery, " B " to connect the battery to the buzzer, and " C " to connect the battery to the lamp. The " Plane of coil " is *diagonal* and lies in a vertical plane parallel to a line through the multiplier

SCHEMATIC DIAGRAM FOR SCR-125-A

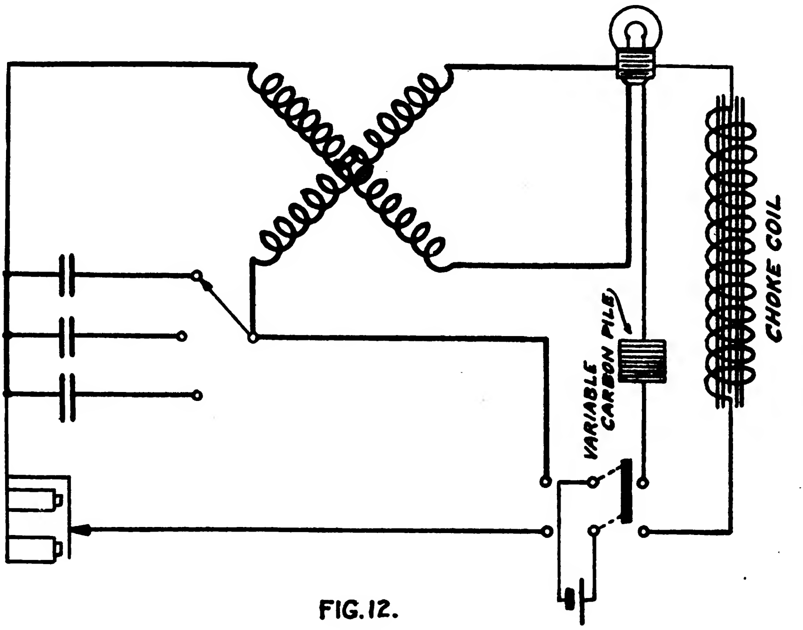

FIG. 12.

switch and the lamp. The following brief instructions are contained on the inside of the set box cover:

This instrument has three wave length ranges obtained by three values of capacity. With the condenser switch on position 1, the wave length range is approximately 150 to 450 meters. The wave length dial reads directly in meters. With the condenser switch on position 3, the wave lengths indicated on dial must be multiplied by 3, and correspondingly with the condenser switch on position 1/3, the dial reading must be multiplied by 1/3.

To measure wave length, set circuit switch on " C " and adjust the carbon resistance until the lamp glows a dull red. Couple the wavemeter by holding it near the inductance coil of the sending set. Rotate the dial slowly until the lamp shows maximum brilliance. The wave length will then be indicated on the wavemeter dial.

To set the receiver for a given wave length, set the circuit switch on "B." Adjust the buzzer to give a clear note, and turn the dial to the desired wave length. Couple as above and tune the receiver until the buzzer is heard loudest in telephone receiver.

65. The SCR–128.—This is a *single-scale* wavemeter for very short wave lengths, with a range from 50 to 75 meters. It is so closely similar to the SCR–95 that the same general instructions, wiring diagram, etc., may be used for both meters.

Section XII.

WAVEMETER; TYPE SCR–137.

66. Use and range of wave lengths.—This wavemeter can be used at either a damped or a continuous wave transmitter, and at a receiver with an oscillating vacuum tube detector for all purposes, except the measurement of the logarithmic decrement of a transmitter. With the equipment that has been provided it can *not* function at a receiver with a crystal or other nonoscillating detector. Its range of wave lengths is from 1,000 to 20,000 meters.

67. Description of meter.—The meter is the Bureau of Standards "Long Wave Meter, type L." It uses a set of coils for the inductance and a variable air condenser for the capacity. It is provided with a thermo-galvanometer, and binding posts for connection to an external detector, buzzer, etc. All parts are mounted on a panel in an oak box with a removable cover, and the meter is self-contained. A top view is shown in Fig. 13. The over-all dimensions are approximately 8¼ by 16¾ by 10¼ inches high and the weight about 28 pounds.

68. Component parts.—Four *coils* are provided permanently mounted on the underside of the panel and are connected into circuit in three combinations for the three scales of wave lengths, as follows: (1) For short waves, 1,000 to 5,000 meters, the four coils are all in parallel; (2) for medium waves, 2,000 to 10,000 meters, two coils are connected in series and this combination is in parallel with the other two coils, also in series; and (3) for long waves, 4,000 to 20,000 meters, the four coils are all in series. These various connections are made by means of a switch which is operated by the handle near the

rear edge of the meter. This handle can be turned in either direction and at the three points in the revolution where the connections are made, the number of the scale in use is indicated in a circle at the peephole near the handle, and at the same time the index points to the direct reading scale of wave lengths in use. The coils are in the right-hand end of the set box and the axis of the coils is parallel to the right end, as indicated by the legend "Axis of Coils" on the end. The plane of the windings is therefore parallel to the front and rear of the box.

The *condenser* is of the mechanically balanced type with two sets of fixed plates and two sets of moving plates. Owing to the rapid change of capacity as the moving plates are rotated, the motion is geared down about 5½ to 1 and the condenser handle is the one near

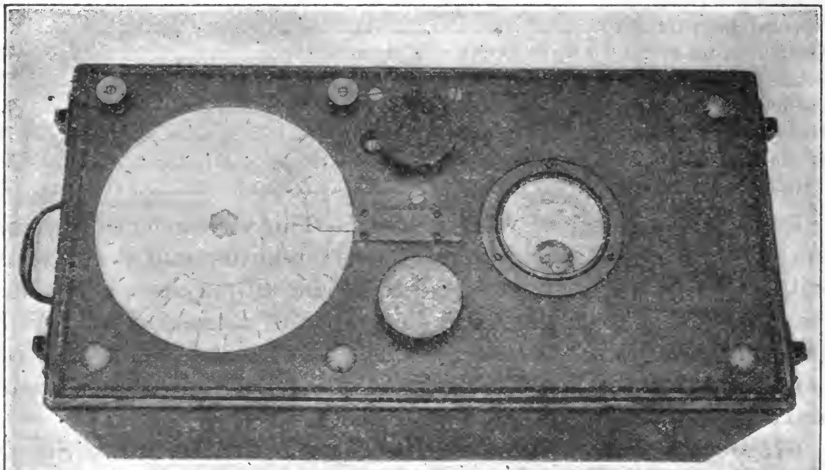

FIG. 13.

the front edge of the panel marked "Press." The condenser compartment is in the left end of the set box shielded by a metal lining.

The *galvanometer* is provided with a small screw extending through the glass cover so that its needle can be adjusted to zero if desired. It is shunted by a resistance and is cut out of circuit by a switch which is closed except when the condenser handle is *pressed down*. This pressure does not change the condenser reading or wave length.

No other auxiliary apparatus has been provided with the meter. There are, however, two binding posts on the rear edge of the panel which are connected to the terminals of the condenser. A detector and telephones, or buzzer and battery can be connected to these if desired for use as described in Section VII. The schematic wiring diagram of the wavemeter is shown in figure 14.

69. General instructions.—Before making any measures with the wavemeter, reference should be made to Sections IV, V, VI, and VII for the various points which must be observed in the care of meters and their use at a transmitter and at a receiver. In making the meter ready for transportation the only step that need be taken is to be sure that the cover is firmly clamped in place.

SCHEMATIC DIAGRAM FOR SCR-137

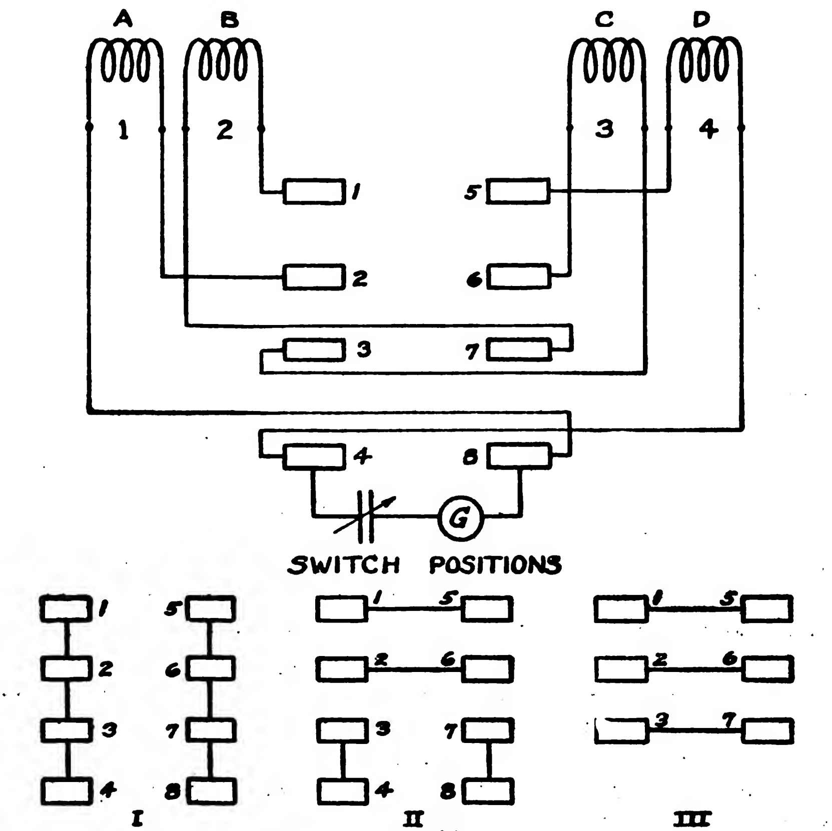

FIG. 14.

70. Measuring an unknown wave length at a transmitter.—Set the coil switch at the rear edge of the meter on the scale that includes within its range the wave length to be measured, taking care that the circle containing the scale number is central in the peephole. Loosely couple the wavemeter coils with the *antenna coil* of the transmitter; press down on the condenser handle on the front edge of the panel; and turn it slowly over its scale until a maximum reading is obtained on the galvanometer, thus indicating that the

wavemeter is in resonance with the transmitter. Read the wave length in meters on the scale in use.

If an *external detector* and telephones are to be used (as at a spark transmitter), they should be connected either in series between the two binding posts or in a unipolar connection to the inner post. Then set the coil switch, etc., similar to the previous paragraph.

71. Setting a transmitter at a predetermined wave length.—Set the coil switch on the scale that includes within its range the predetermined wave length; set the condenser at the wave length; make no connections to the wavemeter; press down on the condenser handle; and do not change the wavemeter adjustments thereafter. Loosely couple the wavemeter coils with the *antenna coil* and tune the transmitter to the wavemeter until the galvanometer shows by its maximum reading that the two circuits are in resonance at the predetermined wave length. At a *spark* transmitter it may be more convenient to tune the wavemeter to the transmitter, as described in paragraph 22.

72. Calibrating a transmitter.—The procedure is the same as in the previous paragraph except that the transmitter is set in succession at a series of predetermined wave lengths, etc., as described in paragraphs 19 and 20.

73. Measuring an unknown wave length at a receiver.—If the receiver is provided with an *oscillating vacuum tube detector* (autodyne) two methods may be used, one in which the wavemeter is provided with a buzzer as described in the latter part of this paragraph; and the other with no auxiliary apparatus, which is preferable, as follows: Set the coil switch on the scale that include within its range the wave length to be measured; make no connections to the wavemeter; and loosely couple the wavemeter coils with the proper receiving circuit coil, as described in paragraph 24. Turn the condenser handle of the wavemeter slowly over its scale until a "Resonance click" is heard in the telephones of the receiving set (see paragraph 78), which thus indicates that the wavemeter is in resonance with the receiving circuits at the unknown wave length. Read the wave length in meters on the scale in use.

If the receiver is provided with a *crystal* or *vacuum tube detector* (nonoscillating), the following directions are to be followed: Connect an external buzzer and dry-cell battery in series to the two binding posts at the rear of the panel. Then set the coil switch on the scale that includes within its range the wave length to be measured and adjust the buzzer to a clear, steady note. Loosely couple the wavemeter coils with the proper receiving circuit coil, as described in paragraph 24. Turn the condenser handle of the wavemeter slowly over its scale until the loudest signals are heard in the telephones of the receiving set, thus indicating that the receiving cir-

cuits are in resonance with the wavemeter at the unknown wave length. Read the wave length in meters, etc.

74. Setting a receiver at a predetermined wave length.—At a receiver with an *oscillating vacuum tube detector*, set the coil switch on the scale that includes the predetermined wave length, and the condenser on the wave length; make no other connections to the wavemeter; and do not change the wavemeter adjustment thereafter. Loosely couple the wavemeter with the proper receiving circuit coil, as described in paragraph 24; and tune the receiver circuits to the wavemeter as though it were a distant station until a "Resonance click" is heard in the telephones of the receiving set, thus indicating that the circuits are in resonance with the wavemeter at the predetermined wave length. (See paragraph 78.)

At a receiver with a *crystal* or *vacuum tube detector* (nonoscillating), set the coil switch on the scale that includes the predetermined wave length, and the condenser on the wave length; connect the battery and buzzer as in paragraph 73; adjust the buzzer to a clear, steady note; and do not change the wavemeter adjustments thereafter. Loosely couple the wavemeter coils with the proper receiving circuit coil, as described in paragraph 24; and tune the receiving circuits to the wavemeter as though it were a distant station, until the telephones of the receiver indicate by the loudest signals that the circuits are in resonance with the wavemeter at the predetermined wave length.

75. Calibrating a receiver.—The procedure is the same as in the previous paragraph except that the wavemeter is set in succession at a series of predetermined wave lengths, etc., as described in paragraph 27.

SECTION XIII.

HETERODYNES AND AUTODYNES AS WAVEMETERS.

76. Uses.—A heterodyne set calibrated in wave lengths can be used as a wavemeter at a receiving set provided with an oscillating tube detector. Similarly, a receiving set with an oscillating tube detector (autodyne) calibrated in wave lengths can be used as a wavemeter at a continuous wave transmitter. Other uses of heterodynes and autodynes as substitutes for wavemeters may be devised, but will not be described in this pamphlet.

77. Beat note test for resonance.—In all uses of the heterodyne wavemeter, both the heterodyne and other circuits must be oscil-

lating. When the two circuits are oscillating at nearly the same wave length, a "*beat*" note is heard in the telephones of the receiving set. The pitch of the beat note will vary with the tuning adjustments of either circuit. If the tuning adjustments of either circuit are slowly and continuously varied through resonance, the beat note will pass from inaudibly high to high pitch, becoming lower and lower in pitch until it becomes inaudibly low; after which it will reappear as a note of low pitch which becomes higher and higher, finally becoming inaudibly high. The two circuits are in resonance when the beat note is of zero pitch—that is, in the inaudibly low range of tuning. This point is halfway between the points where the low note disappears and reappears as the tuning is varied.

78. "Click" test for resonance.—When a steady current flows through a telephone receiver—as in a vacuum tube detector—any sudden change in the current will produce a click in the receiver. Thus in an autodyne which is oscillating there will be a sudden decrease in the current if a near-by circuit is tuned to the same wave length, as the near-by circuit then draws a large amount of energy from the autodyne circuit and decreases the current in the telephone. When a "click" is produced by this cause it therefore indicates resonance between the autodyne and the external circuit.

79. Autodyne at a transmitter.—A receiving set with an oscillating tube detector and calibrated in wave lengths can be used to measure unknown wave lengths at a continuous wave transmitter. In this case the primary of the receiver is left open circuited and the coupling between the primary and secondary of the receiver made as loose as possible. In general, the secondary of the receiver will pick up energy enough from the transmitter to give a signal without the use of the receiver primary circuit and with no special regard to coupling. Leaving the transmitter circuits unchanged, adjust the receiving circuit to resonance (zero beat note). Similarly a transmitter can be set at a predetermined wave length and calibrated. (See paragraphs 19 and 20.)

80. Heterodyne at a receiver.—A heterodyne set can be used to measure unknown wave lengths, etc., at a receiver in several different ways as follows: It may be connected (1) in the antenna circuit; (2) in the secondary circuit; or (3) loosely coupled with the proper receiving circuit coil but not connected into circuit. In the first case the secondary circuit must remain unchanged and the heterodyne set adjusted to produce zero beat signals as shown by the telephones of the receiving circuit; in the second case, the primary circuit must remain unchanged, etc.; and in the third case, both circuits must remain unchanged, etc. The first and third methods are the most commonly used. The Signal Corps set, type BC-104,

may be used for the first method. Similarly a receiving circuit can be set at a predetermined wave length and calibrated according to the directions of paragraphs 26 and 27.

SECTION XIV.

THEORY OF DAMPING AND ITS MEASUREMENT BY DECREMETER AND WAVEMETER.

81. Damped oscillations and logarithmic decrement.—Whenever a condenser discharges through an inductance and a resistance, the discharge current in general takes place as a train or series of oscillations, the first of which is the most intense, and the following ones of steadily decreasing values as they die away to zero. Such a train of oscillations is said to be *damped*, and the *logarithmic decrement* is the *mathematical measure* of the damping, or the dying away of the oscillations. If the oscillations in a train die away quickly, the decrement is said to be large; and if they die away slowly, the decrement is said to be small. The damping of tube and arc sets is practically zero, and for this reason measures of damping are confined to spark sets.

82. Mathematical definition of decrement.—Mathematically, decrement may be defined as follows: Let figure 15 represent part of a wave train. The largest value in a positive or negative half cycle or alternation is called the *amplitude:* Thus I_0, I_1, and I_2 are the three amplitudes of figure 15, in which I_0 is the largest amplitude and I_1 and I_2 are amplitudes of successive half cycles in the wave train as it dies away. In mathematical language the logarithmic decrement is defined as the natural logarithm of the ratio of any amplitude to the next following amplitude in the same direction.

$$\text{Decrement} = \delta = \log \frac{I_0}{I_2}$$

where δ (read "delta") is the symbol for the decrement. It is constant in any one wave train.

This may be rewritten and restated in other ways as follows:

$$\delta = \log I_0 - \log I_2$$

Thus the decrement is a number which is the *constant difference* between the natural logarithms of any two successive amplitudes in the same direction.

$$\delta = \log I_0 - \log I_2$$

$$\text{And } \log I_2 = \log I_0 - \delta$$

Thus the decrement is the constant number by which the natural logarithm of the amplitude of any oscillation in a train must be decreased to find the natural logarithm of the next following amplitude in the same direction. In other words, it is a constant decrement or decrease in a natural logarithm, whence the name "logarithmic decrement."

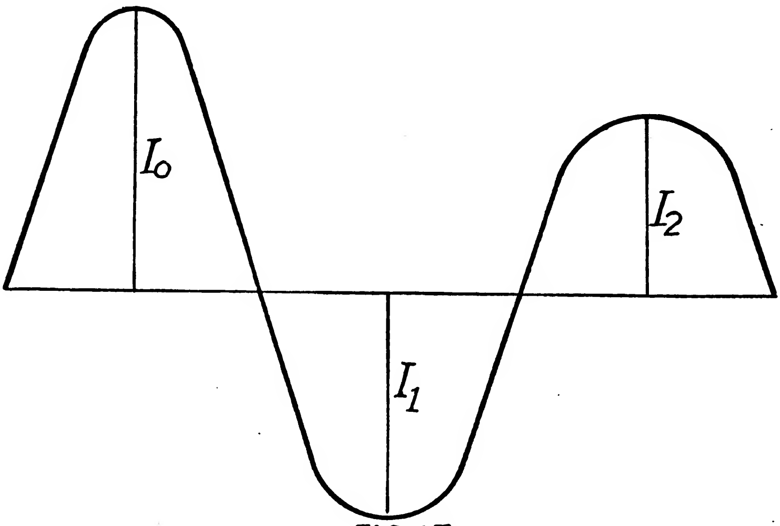

FIG. 15.

If $I_0 = I_2 = I_4$, etc., that is, if the amplitude of all the oscillations in the train is the same, it is evident that the logarithmic decrement is zero, and these oscillations are *undamped*. Reference will be made to this relation later on in the theory of the decremeter.

83. Calculation of decrement in an isolated circuit.—The decrement of any isolated or very loosely coupled oscillating circuit can also be defined by its *electrical constants*, as in the following formula:

$$\delta = \frac{R}{2\,LN}.$$

R=High frequency resistance in ohms.
L=Inductance in henrys.
N=Number of cycles per second at which the circuit is oscillating.

The quantity N is connected to the wave length λ by the following formula:

$$N\lambda = V = 300{,}000{,}000 \text{ meters per second where } \lambda \text{ is in meters.}$$

For example, if the wave length is 754, the value of N is $\frac{300{,}000{,}000}{754}$, or about 398,000 cycles per second.

84. General formulas.—When the decremeter is used to measure the wave length or the decrement of a transmitter, it is loosely coupled with its circuit. Under these conditions it can be shown mathematically that by means of suitably chosen readings the decrement of the transmitter can be determined by the following formula which makes use of the decrement of the meter itself, as well as certain readings of its capacity and current:

$$\delta_1 + \delta_2 = \pi \frac{C_r - C}{C} \sqrt{\frac{I^2}{I^2_r - I^2}}$$

δ_1 is the decrement of the transmitting circuit under measurement.

δ_2 is the decrement of the meter itself.

C_r is the capacity of the decremeter condenser when it is in resonance with the transmitter.

I^2_r is the square of the current in the decremeter circuit at resonance.

C is the capacity of the decremeter condenser when it is slightly off resonance, or detuned.

I^2 is the square of the current in the decremeter circuit at the detuned adjustment.

In order to avoid the necessity of squaring the ammeter current reading to get I^2, the meter actually provided has its scale graduated as I^2 or it is a "current squared" meter. It is a hot wire wattmeter or galvanometer, whose reading depends upon its I^2R value. The resistance "R" of the wire is fixed so that the readings are proportional to the square of the current.

85. Simplified formulas.—In practically all cases where the decrement formula can be correctly used, it is possible to simplify it by a suitable choice of its readings. If the reading I^2 at the capacity C is so taken that $I^2 = \frac{1}{2} I^2_r$, then the quantity under the square root sign becomes unity, and hence

$$\delta_1 + \delta_2 = \pi \frac{C_r - C}{C}$$

where all the quantities are known except δ_1, which can be computed.

If the decremeter is loosely coupled to an undamped wave source, as a vacuum tube oscillator, whose decrement is zero, and if the readings are taken in the usual way, the decrement of the meter can be

immediately determined, as δ_1 is now zero, and all quantities are known except δ_2 which becomes

$$\delta_2 \pi = \frac{C_r - C}{C}.$$

From formula $\delta = \frac{R}{2LN}$ it is seen that the decrement will vary with N and hence with the wave length, as well as with the high frequency resistance R, and that, therefore, it is not constant for any one decremeter coil. It is the general practice, however, to give an *average* value for each coil over the range of wave lengths for which it is to be used. In some cases for accurate work a curve is supplied showing the variation in decrement for each coil over the entire range of its use.

86. Decremeter scale.—It can be shown mathematically that the plates of the decremeter condenser can be so shaped that for any change in capacity from C_r to C, the quantity $\frac{(C_r - C)}{C}$ will be constant. If a scale is attached to the variable condenser whose value is proportional to $\frac{(C_r - C)}{C}$ and whose readings are π times $\frac{(C_r - C)}{C}$, it is evident that the scale will read directly $\delta_1 + \delta_2$ in accordance with the formula of paragraph 85. From the known value of δ_2, δ_1 can be immediately determined. A wavemeter whose condenser is designed to give such readings is called a decremeter. The complete theory of the decremeter is given in Bureau of Standards Scientific Paper No. 235.

87. Use of a wavemeter as a decremeter.—Although the logarithmic decrement can be obtained from a direct reading scale of a decremeter, yet it can also be obtained by computation from readings of certain types of wavemeters. For this purpose, (1) the wavemeter must be of the type using a fixed inductance and variable capacity; (2) its own decrement must be known; and (3) it must be provided with either a current measuring instrument, as an ammeter, or preferably a "current squared" instrument, as a hot wire galvanometer or a thermo-galvanometer.

If the wavemeter coil is loosely coupled with the antenna coil of the transmitter, and if the capacity of its condenser is varied, it will be found that the ammeter or galvanometer will show a maximum reading when the wavemeter is in resonance with the transmitter, and steadily decreasing readings as the condenser is varied more and more from its resonant position on either side of the resonance point. When these results are plotted with the condenser capacities along the horizontal line and the square of the currents along the vertical line, the curve so obtained is one form of a *resonance curve.*

88. Example of a wavemeter used as a decremeter.—Such a resonance curve is shown in figure 16, and from it the logarithmic decrement can be computed as follows: Referring to paragraph 85, it

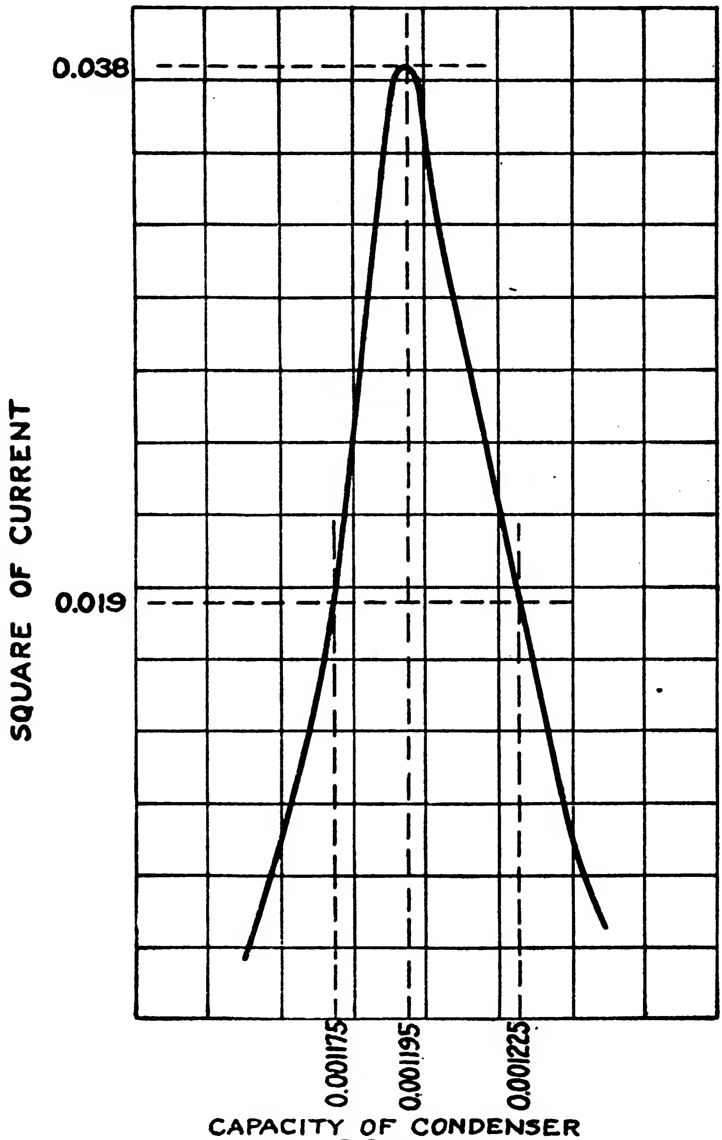

FIG. 16.

is seen that it is necessary to know the capacity at resonance, C_r, where the galvanometer reads $I^2{}_r$; and at the detuned position C, where the galvanometer reads $\frac{1}{2}I^2{}_r$. From the curve, C_r is 0.001195

mfd. at $I^2_r=0.038$ and C is 0.00117 mfd. at $\frac{1}{2}I^2_r$ Substituting in the formula, the formula

$$\delta_1+\delta_2=3.14\frac{0.001195-0.001175}{0.001175}=0.054.$$

If δ_1 is given as 0.016, then δ_2, the decrement of the transmitter is 0.038.

In the computation of the logarithmic decrement in the previous paragraph, the capacity at resonance and at a detuned position on one side of resonance was used. Inasmuch as the curve is not exactly symmetrical, it is best to compute another value, using the capacity at resonance and at the detuned position on the other side of resonance. Thus

$$\delta_1+\delta_2=\pi\frac{C-C_r}{C}$$

where C_r is 0.001195 mfd. at $I^2_r=0.038$ as before; and C is also 0.001225 mfd. at $\frac{1}{2}I^2_r$. Substituting in the formula, $\delta_1+\delta_2=0.077$ and $\delta_2=0.061$ The average of the two values of δ_1 is therefore 0.049.

Although the method of thus computing the decrement twice and taking its average is strictly correct, yet it is somewhat quicker in practical work to combine the two formulas and methods as follows:

$$\delta_1+\delta_2=\frac{\pi}{2}\times\frac{C_1-C_2}{C_r}$$

where C_1 is the detuned capacity on the large capacity side of resonance at the point where $I^2=\frac{1}{2}I^2_r$;

C_2 is the detuned capacity on the small capacity side of resonance at the corresponding point;

and C_r is the capacity at resonance.

Substituting in the formula $\delta_1+\delta_2=0.066$ and hence δ_2, the decrement of the transmitter$=0.050$, which agrees closely with 0.049 as obtained above.

In some cases it is more convenient to plot another form of resonance curve, especially where the values of the wavemeter capacities are not given, but only those of the wave lengths in meters. The formula is slightly changed, as follows:

$$\delta_1+\delta_2=\pi\frac{\lambda_1-\lambda_2}{\lambda_r}.$$

where λ_1 is the wave length at the detuned position on the long wave length side of resonance at the point where $I^2=\frac{1}{2}I_r^2$;

λ_2 is the wave length at the detuned position on the short wave side of resonance at the corresponding point;

and λ_r is the wave length at resonance.

89. Notes on the use of a wavemeter as a decremeter.—In the previously described methods of measurement of decrement, a "cur-

rent-squared" instrument was used to indicate resonance, but the same measures can also be made under certain conditions with an ammeter. In this case another form of resonance curve is drawn, in which the condenser capacities or wave lengths in meters are plotted along the horizontal line and the currents along the vertical line. The values of the capacity or wave length are taken at resonance as before, but the detuned values must be taken where I is at 0.707 I_r and not at $\frac{1}{2}I_r^2$, as will be seen from the following: The relative positions of I_r and 0.707 I_r on the resonance curve of the currents is the same as that of I^2_r and $\frac{1}{2}I_r^2$ on the resonance curve of the squares of the currents, for if each value on the former is squared the latter curve is obtained and I_r and 0.707 I_r become I_r^2 and $\frac{1}{2}I_r^2$. Thus the previous formulas can be used if the detuned capacities or wave lengths are read from the current curve at I_r and 0.707 I_r.

The previously mentioned resonance curves can be more accurately taken and the decrement more accurately computed, the smaller the resistance and decrement of the wavemeter. It is thus seen why the wavemeter or decremeter resistances in coil, condenser, and wattmeter should be kept as low as possible. The sharpness of the peak of the resonance curve depends upon the sum of the decrements of the circuit under measurement and of the wavemeter. In general, the smaller the sum of the decrements the sharper the peak, and vice versa, the larger the sum the broader the peak. It must be noted that a wavemeter with a variable inductance can *not* be used in measuring a decrement.

Section XV.

DECREMETER; TYPE SCR–87.

Paragraph.

90. Use and range of wave lengths.—This decremeter can be used at either a damped or a continuous wave transmitter and at a receiver for all purposes as a wavemeter as well as a decremeter. It is designed especially for the measurement of the logarithmic decrement of a transmitter, as described at length in Section XIV. Its range of wave lengths is from 75 to 3,000 meters and of decrement from zero to 0.30.

91. Description of meter.—The meter is of the type that uses a set of coils for the inductance; and a special variable air condenser for the capacity. It is provided with a thermo-couple galvanometer; crystal detector and telephone; and with battery and buzzer, etc. Some of the parts are mounted on a panel and the rest are carried in

FIG. 17.

the cover. The meter is self-contained in a leather case with hinged cover and carrying strap. It is shown assembled in figure 17, and with an interior view in figure 18. The over-all dimensions are $10\frac{1}{4}$ by $10\frac{3}{4}$ by $9\frac{3}{4}$ inches high, and its weight is about 20 pounds.

92. Component parts.—Four *coils* are provided, numbered 1 to 4, which are stored away in the cover of the case under a clamp which

also holds the galvanometer in place. Each coil is provided with a special plug to which the coil terminals are connected. A coil is connected into a circuit by plugging it into the jack in the upper right corner of the panel and pressing it down until it is seated. This automatically sets a pointer to read on a scale of wave lengths at the condenser corresponding to the coil in use, as follows: (1) 60 to 200 meters; (2) 150 to 480 meters; (3) 400 to 1,300 meters; and (4) 1,000 to 3,200 meters.

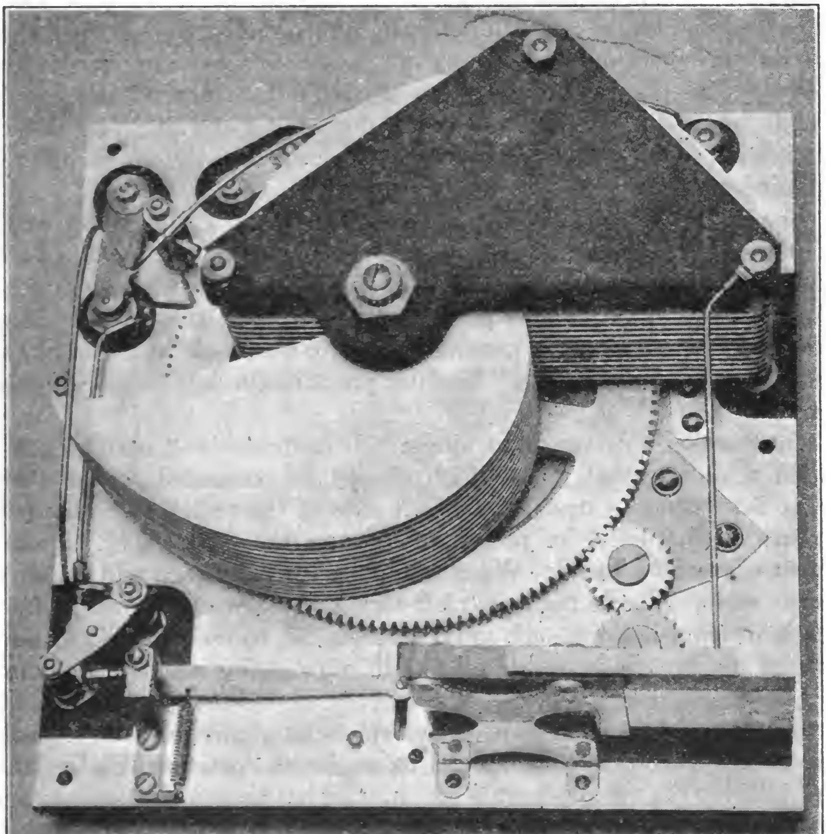

FIG. 18.

The *condenser* is a variable air condenser with specially shaped fixed and moving plates. The moving plates can be clamped by turning the "Lock" switch on the left edge of the panel so that the arrow points in toward the meter, and should always be *so clamped* for transportation. The rotation of the plates is geared down so as to be able to get a fine adjustment and for this reason the condenser handle is off center and in the lower right-hand corner of the panel. The moving plates are grounded on the metal lining of the con-

denser compartment. The condenser handle carries the scale of decrements, 0.00 to 0.30; and the condenser shaft carries the four wave-length scales and a depressed scale of degrees which can be read through a slot near the top of the panel. There is a small fixed air condenser in parallel with the variable condenser.

Resonance may be indicated either by (1) a thermo-galvanometer or (2) crystal detector and telephones. The *galvanometer* is stored away on the cover of the case in the center of the coils by inserting its plugs into jacks provided for this purpose. It is provided with an adjusting screw extending through the glass cover so that the needle can be set on the zero mark. It is connected into circuit by inserting its plugs into the jacks in the left corner of the panel which puts the meter in series in the decremeter circuit. The meter is shunted by a low resistance so as to keep the decrement of the circuit low.

The *crystal detector* is galena (lead sulphide) in light contact with a fine wire, the pressure of which is adjustable by means of a ball and socket joint. It is connected in series with the telephone in a shunt circuit between two points on the fixed plates of the condenser. The *telephone* is provided with tip terminals and should be connected to the two "*Tel*" binding posts in the left corner of the panel.

The *buzzer* is driven by a single "*Silver chloride*" battery provided with terminal lugs, which should be connected to the two "*buz bat*" binding posts on the left side of the panel. The buzzer circuit is completed by pressing down on the "*buz key*" on the upper edge of the panel. When not in use the battery should be kept in the spring clips in the upper left corner of the cover. If desired, a single dry-cell battery, such as type BA-4, can be used instead of the special batterv above. The schematic wiring diagram is shown in Figure 19.

93. General instructions.—Before making any measures with the decremeter, reference should be made to Sections IV, V, VI, and VII for the various points which must be observed in the care of the meter and its use at a transmitter and at a receiver. When the meter is not in use, or is to be stored away, or made ready for transportation, the following component parts should be secured in their proper places in the cover: Galvanometer, four coils, battery, telephone, and instruction sheets. The condenser plates should be clamped in place by turning the "Lock" switch so that its arrow points toward the center of the meter.

94. Measuring an unknown wave length at a transmitter.—Connect the coil into circuit which includes within its range the wave length to be measured; unclamp the condenser plates; open-circuit

the detector; disconnect the telephone; open the buzzer switch; and connect the galvanometer into circuit. Make no other connection to the decremeter. Loosely couple the decremeter coil with the *antenna coil* of the transmitter and turn the condenser handle of the decremeter slowly over its scale until a maximum reading is indicated on the galvanometer, thus indicating that the decremeter is in resonance with the transmitter. Read the wave length in meters on the scale corresponding to the coil in use.

If a crystal detector is to be used at a *damped wave* (*spark*) transmitter, the following directions are to be followed: Connect the coil into circuit which includes within its range the wave length to be

SCHEMATIC DIAGRAM FOR DECREMETER TYPE SCR-87

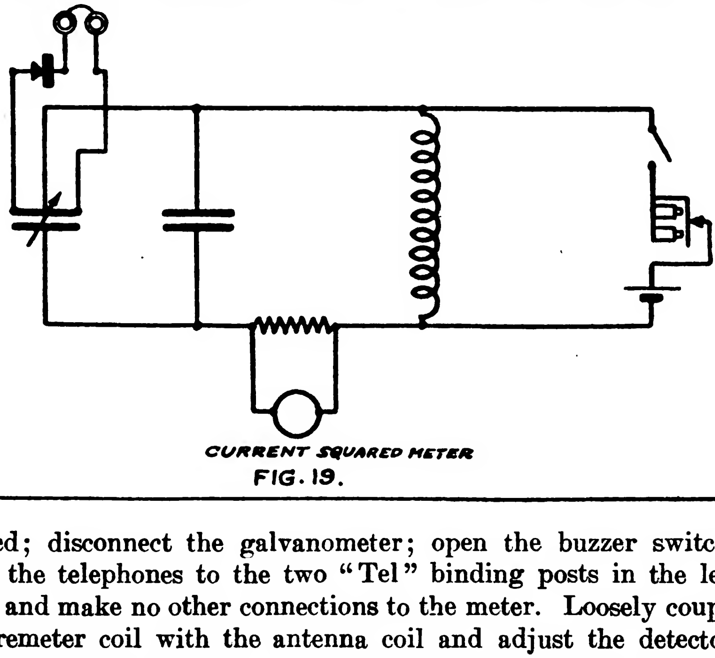

FIG. 19.

measured; disconnect the galvanometer; open the buzzer switch; connect the telephones to the two "Tel" binding posts in the left corner; and make no other connections to the meter. Loosely couple the decremeter coil with the antenna coil and adjust the detector. Turn the condenser handle of the decremeter slowly over its scale until the loudest signals are heard, etc.

95. Setting a transmitter at a predetermined wave length.—Connect the coil into circuit which includes within its range the predetermined wave length; set the condenser on the wave length; open the buzzer switch; connect in the galvanometer or the detector and telephones; and do not change the decremeter adjustments thereafter. Loosely couple the decremeter coil with the *antenna coil* and tune the transmitter to the decremeter until the galvanometer or

telephone shows by its maximum response that the two circuits are in resonance at the predetermined wave length. At a *spark* transmitter, it may be more convenient to tune the wavemeter to the transmitter, as described in paragraph 22.

96. Calibrating a transmitter.—The procedure is the same as in the previous paragraph, except that the transmitter is set in succession at a series of predetermined wave lengths, etc., as described in paragraphs 19 and 20.

97. Measuring an unknown wave length at a receiver.—Connect the coil into circuit which includes within its range the wave length to be measured; disconnect the telephones; open-circuit the detector; connect the battery into circuit; and close the buzzer switch. Loosely couple the decremeter coil with the proper receiving circuit coil, as described in paragraph 24. Turn the condenser handle of the decremeter slowly over its scale until the loudest signals are heard in the telephones of the receiving set, thus indicating that the receiving circuits are in resonance with the decremeter at the unknown wave length. Read the wave length in meters on the scale in use.

98. Setting a receiver at a predetermined wave length.—Connect the coil into circuit which includes within its range the predetermined wave length; set the condenser on the wave length; disconnect the telephones; open-circuit the detector; close the buzzer switch, and do not change the decremeter adjustment thereafter. Loosely couple the decremeter coil with the proper receiving circuit coil, as described in paragraph 24; and tune the receiver circuits to the decremeter as though it were a distant station, until the telephones of the receiver indicate by the loudest signals that the circuits are in resonance with the decremeter at the predetermined wave length.

99. Calibrating a receiver.—The procedure is the same as in the previous paragraph except that the decremeter is set in succession at a series of predetermined wave lengths, etc., as described in paragraph 27.

100. Measuring decrement at a transmitter.—Connect the coil into circuit whose range includes the wave length at which the decrement is to be measured; open-circuit the detector and the buzzer; disconnect the telephones; put the galvanometer into circuit; and make no other connections to the meter. Adjust the galvanometer needle to zero by means of the small screw extending through the glass cover. This must be carefully done as the measures of the decrement depend in part at least on the correctness of this adjustment. Loosely couple the meter coil with the *antenna coil* of the

transmitter; tune the meter to resonance with the transmitter, in which case the deflection of the galvanometer should preferably be about full scale and not less than half scale. If the transmitter is of low power it is best to work with not more than half scale deflection at resonance in order to be certain that the coupling is loose.

As soon as these approximate adjustments have been made, the meter should be firmly put in place on some stand and the coupling varied slightly by turning the meter coil until at resonance the needle of the galvanometer is on some convenient scale marking as full scale or half scale. In any case, it is preferable that this reading be on an even scale division so that the half scale deflection can be quickly and easily obtained. After these two adjustments have been made, *neither the position of the meter nor the coupling should be changed.* Having noted the galvanometer deflection at resonance, turn the condenser knob in the right-hand corner so that the wave length is decreased and until the galvanometer deflection is reduced to one-half the value at resonance. Keeping the condenser knob fixed, turn the ring outside the decrement scale by means of the pin until either of the two index marks rests on the zero mark of the decremeter scale. Keeping the ring fixed, turn the condenser knob back toward resonance and continue on the other side of resonance until the galvanometer reading is again one-half the value at resonance. Read the value on the decremeter scale opposite the same index mark of the ring. This gives one value of $\delta_1+\delta_2$ A second value of $\delta_1+\delta_2$ should be obtained as follows: Set the meter at resonance as before, and noting the scale deflection turn the condenser knob so that the wave length is increased and until the galvanometer deflection is reduced to one-half the value at resonance. As in the previous case, keep the condenser knob fixed; turn the ring by means of the pin until either of its index marks rests on the zero mark of the decremeter scale. Keeping the ring fixed, turn the knob back toward resonance and continue on the other side of resonance until the galvanometer reading is again one-half the value of resonance. Read the value on the decremeter scale opposite the index mark of the ring. This gives a second value of $\delta_1+\delta_2$. Take the average of the two measures of $\delta_1+\delta_2$; subtract the value of δ_1 for the given coil, which gives the decrement, δ_2, of the transmitter at the given wave length.

Detailed instruction sheets are provided with each decremeter which give additional information, calibration curves, decrements of each coil, etc.

Measures of decrement are of value only when a single wave length or "hump" is noted in tuning. The meter can not be correctly used when two waves or "humps" are observed.

Section XVI.

PARTS LISTS OF SETS.

101. Wavemeter, type SCR-60-C.—This comprises:

Battery, type BA-4 (1).
Crystal, type DC-1 (1).
Set box, type BC-50 (1).

102. Wavemeter, type SCR-61.—This comprises:

Battery, type BA-4 (1).
Coil, type C-13 (1).
Coil, type C-14 (1).
Coil, type C-15 (1).
Crystal, type DC-1 (1).
Head set, type P-11 (1).
Set box, type BC-37 (1).
Strap, type ST-5 (1).

103. Wavemeter, type SCR-95.—This comprises:

Battery, type BA-4 (1).
Lamp, type LM-4 (1).
Set box, type BC-40 (1).

104. Wavemeter, type SCR-111.—This comprises:

Battery, type BA-4 (1).
Lamp, type LM-4 (1).
Set box, type BC-49 (1).

105. Wavemeter, type SCR-125.—This comprises the wavemeter set box and the following:

Battery, type BA-4 (1).
Lamp, type LM-4 (2); 1 in use, 1 spare.

106. Wavemeter, type SCR-125-A.—This comprises the wavemeter set box and the following:

Battery, type BA-4 (1).
Lamp, type LM-4 (2); 1 in use, 1 spare.

107. Wavemeter, type SCR-128.—This comprises the wavemeter set box and the following:

Battery, type BA-4 (1).
Lamp, type LM-4 (2); 1 in use, 1 spare.

108. Wavemeter, type SCR–137.—This is self-contained in its box and has no spares nor accessories.

109. Decremeter, type SCR–87.—This is self-contained in its case and cover. The following detachable parts are carried in the cover:

Set of 4 coils (1).
Thermo-galvanometer, Weston (1).
Battery, silver chloride, with clips (1).
Instruction leaflet (1).
Head set, single (1).

SIGNAL CORPS PAMPHLETS.

[Corrected to February, 1922.]

RADIO COMMUNICATION PAMPHLETS.

[Formerly designated Radio Pamphlets.]

No.

1. Elementary Principles of Radio Telegraphy and Telephony (edition of 4-28-21). W. D. D. 1064.
2. Antenna Systems.
3. Radio Receiving Sets (SCR-54 and SCR-54-A) and Vacuum Tube Detector Equipment (Type DT-3-A).
5. Airplane Radio Telegraph Transmitting Sets (Types SCR-65 and 65-A).
9. Amplifiers and Heterodynes. W. D. D. 1092.
11. Radio Telegraph Transmitting Sets (SCR-74; SCR-74-A).
13. Airplane Radio Telegraph Transmitting Set (Type SCR-73).
14. Radio Telegraph Transmitting Set (Type SCR-69).
17. Sets U. W. Radio Telegraph (Types SCR-79-A and SCR-99). W. D. D. 1084.
20. Airplane Radio Telephone Sets (Types SCR-68; SCR-68-A; SCR-114; SCR-116; SCR-59; SCR-59-A; SCR-75; SCR-115).
22. Ground Radio Telephone Sets (Types SCR-67; SCR-67-A). W. D. D. 1091.
23. U. W. Airplane Radio Telegraph Set (Type SCR-80).
24. Tank Radio Telegraph Set (Type SCR-78-A).
25. Set, Radio Telegraph (Type SCR-105). W. D. D. 1077.
26. Sets, U. W. Radio Telegraph (Types SCR-127 and SCR-130) (edition of Nov., 1921). W. D. D. 1056.
28. Wavemeters and Decremeters. W. D. D. 1094.
30. The Radio Mechanic and the Airplane.
40. The Principles Underlying Radio Communication (edition of May, 1921). W. D. D. 1069.

WIRE COMMUNICATION PAMPHLETS.

[Formerly designated Electrical Engineering Pamphlets.]

1. The Buzzerphone (Type EE-1).
2. Monocord Switchboards of Units (Type EE-2 and EE-2-A) and Monocord Switchboard Operator's Set (Type EE-64). W. D. D. 1081.
3. Field Telephones (Types EE-3; EE-4; EE-5).
4. Laying Cable in the Forward Area (formerly designated Training Pamphlet No. 3).
6. Trench Line Construction (formerly designated Training Pamphlet No. 6-a).
7. Signal Corps Universal Test Set (Type EE-65) (edition of Dec., 1921). W. D. D. 1020.
10. Wire Axis Installation and Maintenance within the Division. W. D. D. 1068.

TRAINING PAMPHLETS.

No.

1. Elementary Electricity (edition of Jan. 1, 1921). W. D. D. 1055.
4. Visual Signaling.
5. The Homing Pigeon, Care and Training. W. D. D. 1000.
7. Primary Batteries (formerly designated Radio Pamphlet No. 7).
8. Storage Batteries (formerly designated Radio Pamphlet No. 8).

FIELD PAMPHLETS.

1. Directions for Using the 24–CM Signal Lamp (Type EE–7).
2. Directions for Using the 14–CM Signal Lamp (Type EE–6).

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